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Koizumi et al.

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(45) **Date of Patent: Apr. 5, 2016**

(54) **TIP SYSTEM AND TIP MONITORING CONTROL EQUIPMENT**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 202 days.

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(22) Filed: **Jun. 11, 2012**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Jun. 17, 2011 (JP) 2011-134699

(51) **Int. Cl.**

G21C 17/00	(2006.01)
G21D 3/00	(2006.01)
G21C 17/108	(2006.01)
G21C 17/10	(2006.01)

(52) **U.S. Cl.**

CPC ***G21D 3/001*** (2013.01); ***G21C 17/10*** (2013.01); ***G21C 17/108*** (2013.01); *Y02E 30/40* (2013.01)

(58) **Field of Classification Search**

CPC G21C 7/36; G21C 17/104; G21C 17/108
USPC 376/254
See application file for complete search history.

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Primary Examiner — Jack W Keith
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(57) **ABSTRACT**

A TIP monitoring control equipment has: a process computer, a TIP control panel, and data transmitting unit. The process computer includes a operation input unit, a TIP scanning unit, a first TIP level data transmitting and receiving unit, and a TIP level data storage unit. To a first TIP level data transmitting and receiving unit, an LPRM level signal, an APRM level signal and TIP level data accumulated in the TIP control panel are input in synchronization with a TIP position signal. The TIP control panel includes a TIP driving control unit, a TIP level processing unit, a TIP position processing unit, a TIP level data accumulation unit and a second TIP level data transmitting and receiving unit. The second TIP level data transmitting and receiving unit transmits TIP level data accumulated in the TIP level data accumulation unit to the process computer via the data transmission unit.

4 Claims, 16 Drawing Sheets

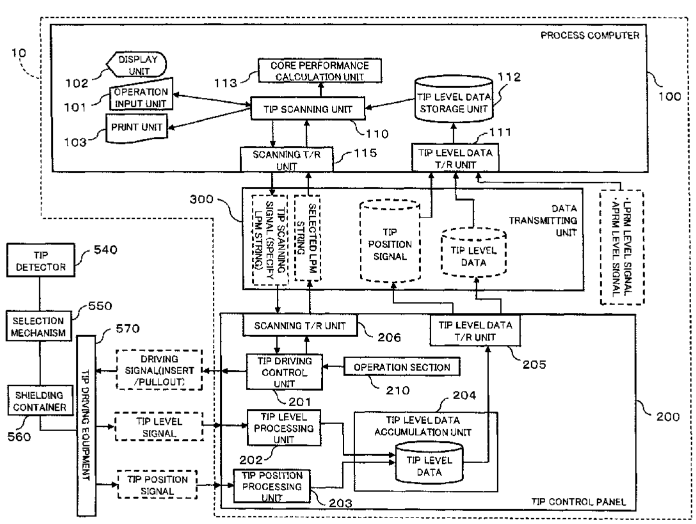

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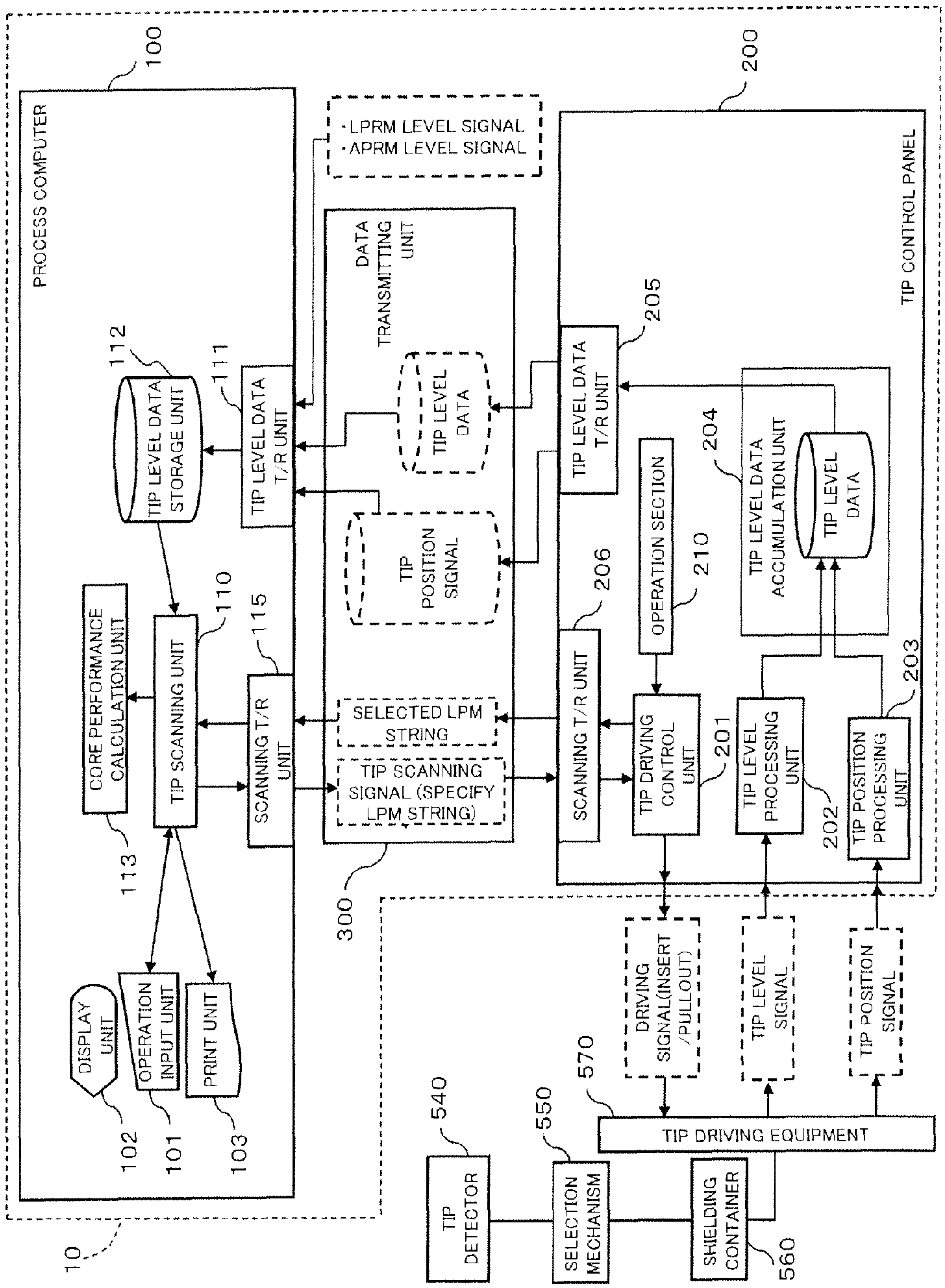
FIG.1



PROCESS COMPUTER
100
TIP LEVEL DATA STORAGE UNIT
112
TIP LEVEL DATA T/R UNIT
111
CORE PERFORMANCE CALCULATION UNIT
113
TIP SCANNING UNIT
110
SCANNING T/R UNIT
115
DISPLAY UNIT
102
OPERATION INPUT UNIT
101
PRINT UNIT
103
10
·LPRM LEVEL SIGNAL
·APRM LEVEL SIGNAL
DATA TRANSMITTING UNIT
TIP LEVEL DATA
TIP POSITION SIGNAL
SELECTED LPM STRING
TIP SCANNING SIGNAL (SPECIFY LPM STRING)
300
TIP CONTROL PANEL
200
TIP LEVEL DATA T/R UNIT
205
OPERATION SECTION
210
TIP LEVEL DATA ACCUMULATION UNIT
204
TIP LEVEL DATA
SCANNING T/R UNIT
206
TIP DRIVING CONTROL UNIT
201
TIP LEVEL PROCESSING UNIT
202
TIP POSITION PROCESSING UNIT
203
DRIVING SIGNAL(INSERT /PULLOUT)
TIP LEVEL SIGNAL
TIP POSITION SIGNAL
TIP DRIVING EQUIPMENT
570
TIP DETECTOR
540
SELECTION MECHANISM
550
SHIELDING CONTAINER
560

FIG. 2

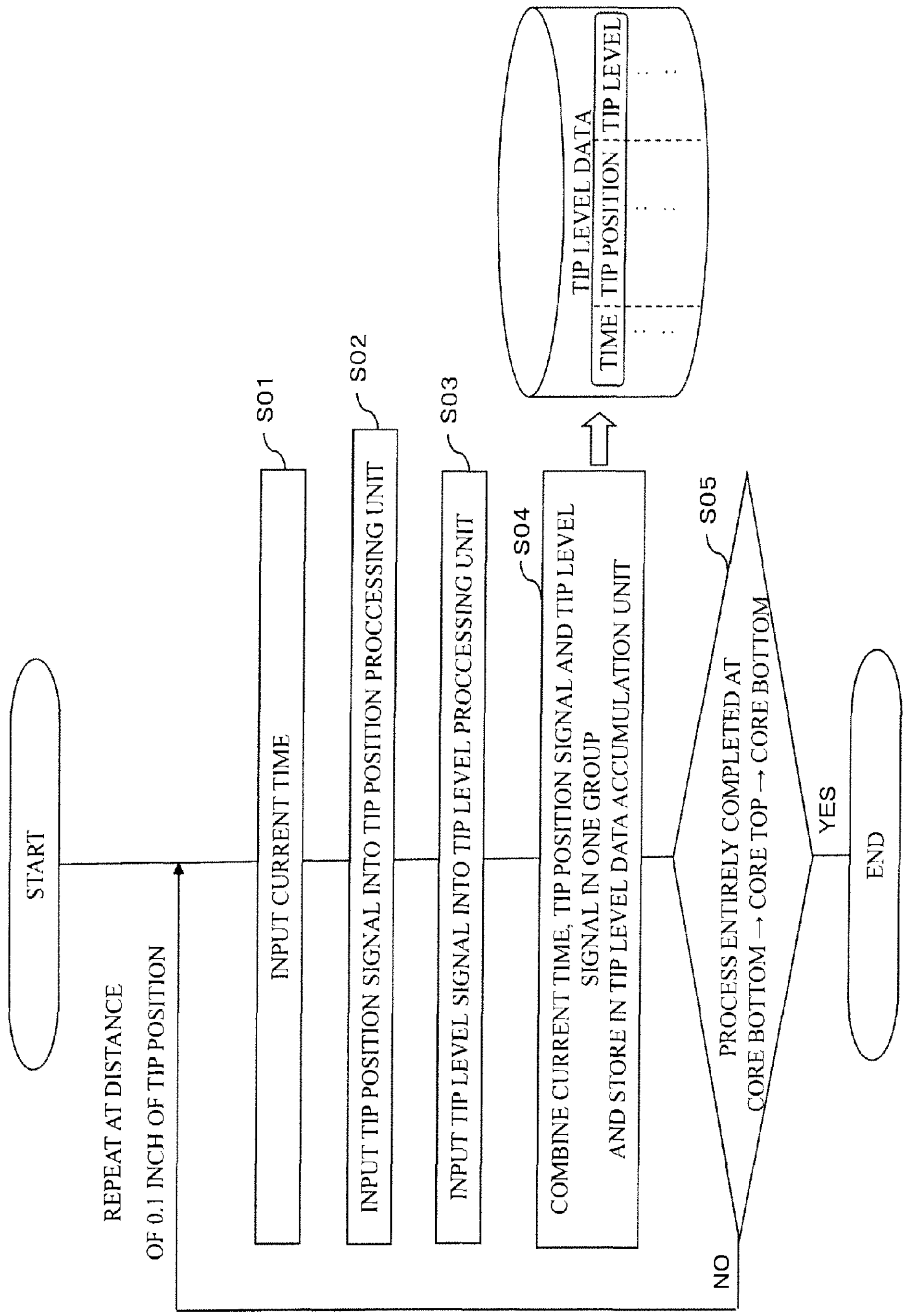

START
REPEAT AT DISTANCE
OF 0.1 INCH OF TIP POSITION
INPUT CURRENT TIME
S01
INPUT TIP POSITION SIGNAL INTO TIP POSITION PROCCESSING UNIT
S02
INPUT TIP LEVEL SIGNAL INTO TIP LEVEL PROCCESSING UNIT
S03
COMBINE CURRENT TIME, TIP POSITION SIGNAL AND TIP LEVEL
SIGNAL IN ONE GROUP
AND STORE IN TIP LEVEL DATA ACCUMULATION UNIT
S04
TIP LEVEL DATA
TIME
TIP POSITION
TIP LEVEL
PROCESS ENTIRELY COMPLETED AT
CORE BOTTOM → CORE TOP → CORE BOTTOM
S05
YES
NO
END

FIG. 3

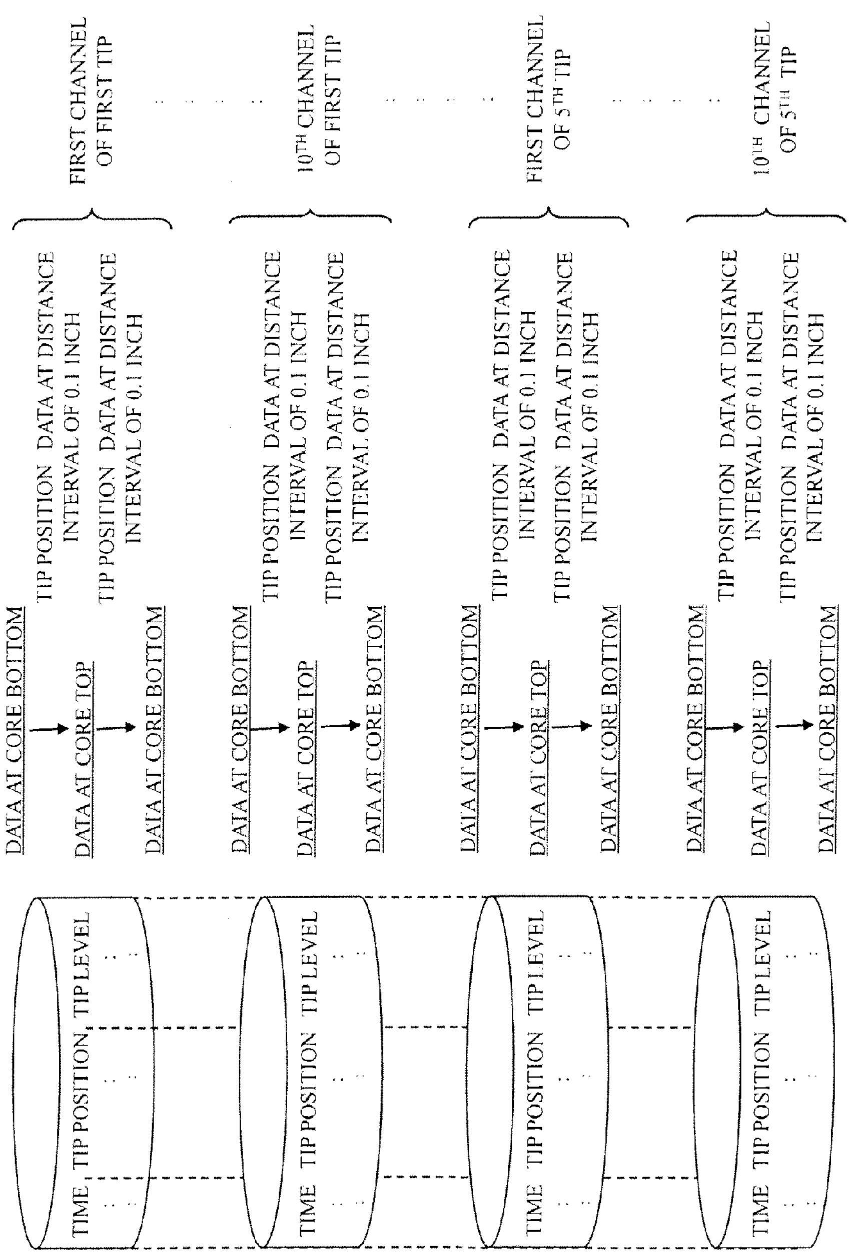

FIRST CHANNEL OF FIRST TIP
10TH CHANNEL OF FIRST TIP
FIRST CHANNEL OF 5TH TIP
10TH CHANNEL OF 5TH TIP
TIP POSITION DATA AT DISTANCE INTERVAL OF 0.1 INCH
TIP POSITION DATA AT DISTANCE INTERVAL OF 0.1 INCH
DATA AT CORE BOTTOM
DATA AT CORE TOP
DATA AT CORE BOTTOM
TIME
TIP POSITION
TIP LEVEL

FIG. 4

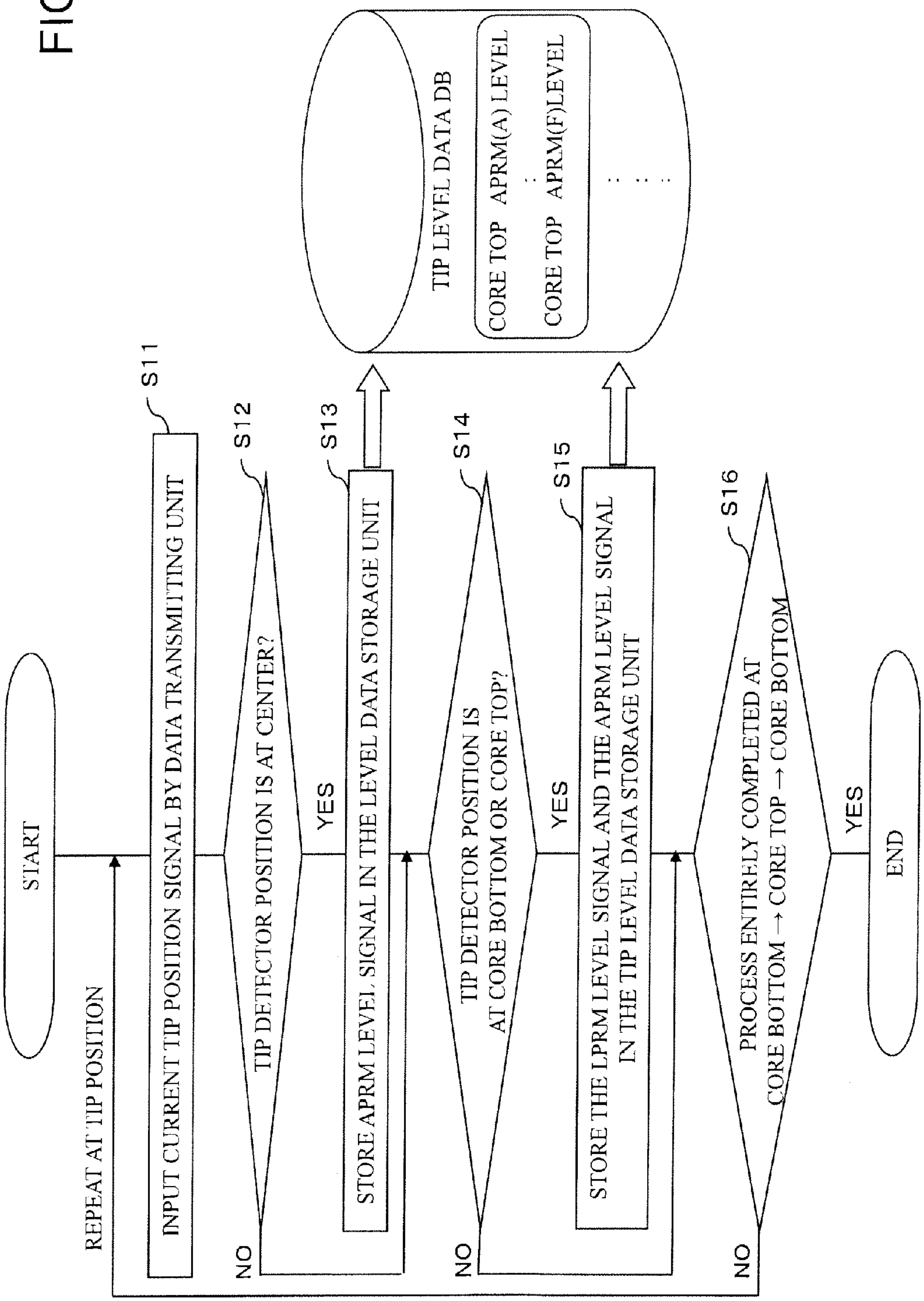

START
REPEAT AT TIP POSITION
S11
INPUT CURRENT TIP POSITION SIGNAL BY DATA TRANSMITTING UNIT
S12
TIP DETECTOR POSITION IS AT CENTER?
YES
NO
S13
STORE APRM LEVEL SIGNAL IN THE LEVEL DATA STORAGE UNIT
S14
TIP DETECTOR POSITION IS AT CORE BOTTOM OR CORE TOP?
YES
NO
S15
STORE THE LPRM LEVEL SIGNAL AND THE APRM LEVEL SIGNAL IN THE TIP LEVEL DATA STORAGE UNIT
S16
PROCESS ENTIRELY COMPLETED AT CORE BOTTOM → CORE TOP → CORE BOTTOM
YES
NO
END
TIP LEVEL DATA DB
CORE TOP APRM(A) LEVEL
CORE TOP APRM(F)LEVEL

FIG. 5

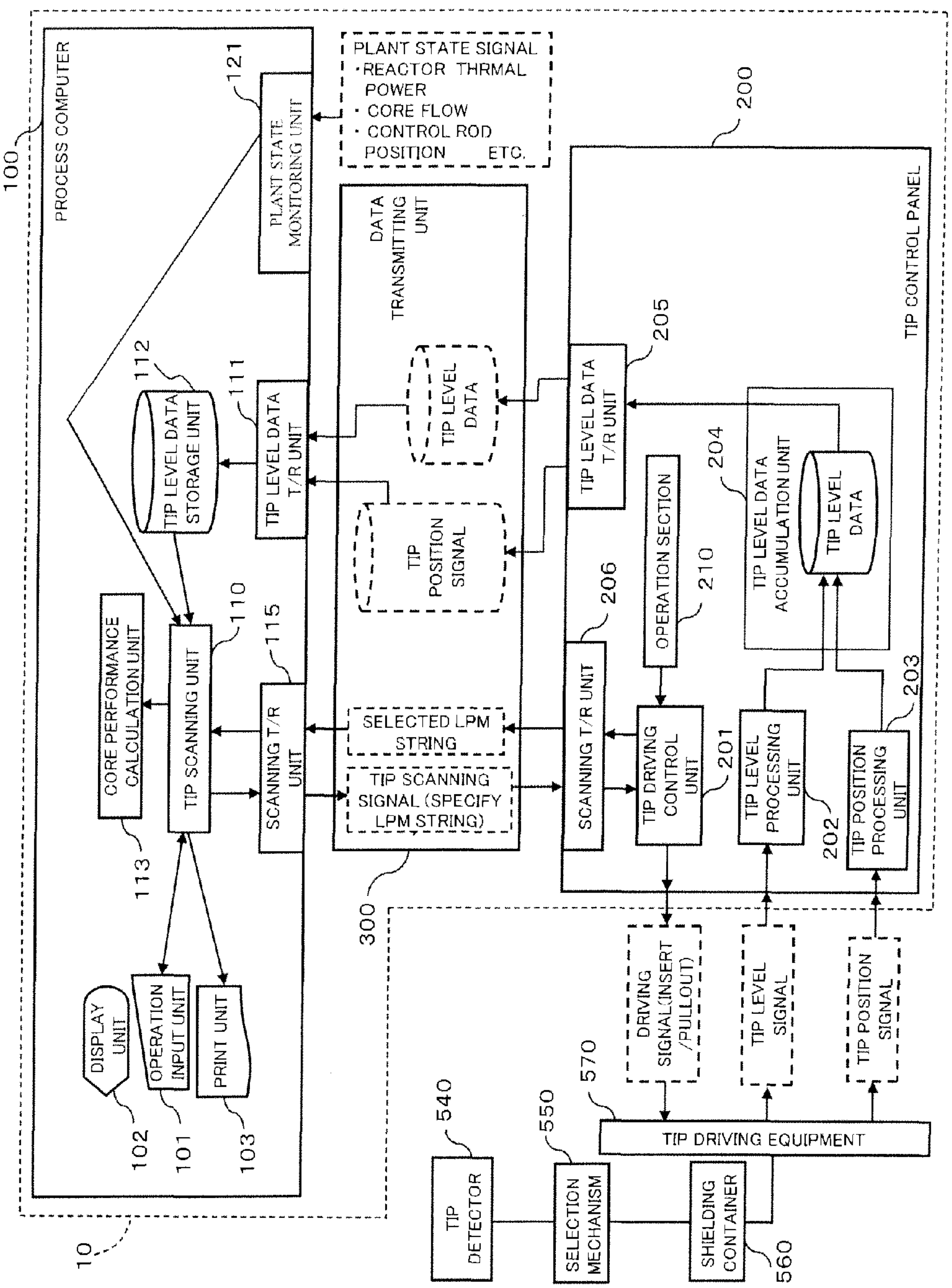

10
100
PROCESS COMPUTER
121
PLANT STATE MONITORING UNIT
PLANT STATE SIGNAL
·REACTOR THRMAL POWER
· CORE FLOW
· CONTROL ROD POSITION ETC.
112
TIP LEVEL DATA STORAGE UNIT
111
TIP LEVEL DATA T/R UNIT
110
TIP SCANNING UNIT
113
CORE PERFORMANCE CALCULATION UNIT
115
SCANNING T/R UNIT
102
DISPLAY UNIT
101
OPERATION INPUT UNIT
103
PRINT UNIT
300
DATA TRANSMITTING UNIT
TIP LEVEL DATA
TIP POSITION SIGNAL
SELECTED LPM STRING
TIP SCANNING SIGNAL (SPECIFY LPM STRING)
200
TIP CONTROL PANEL
205
TIP LEVEL DATA T/R UNIT
204
TIP LEVEL DATA ACCUMULATION UNIT
TIP LEVEL DATA
210
OPERATION SECTION
206
SCANNING T/R UNIT
201
TIP DRIVING CONTROL UNIT
202
TIP LEVEL PROCESSING UNIT
203
TIP POSITION PROCESSING UNIT
DRIVING SIGNAL(INSERT /PULLOUT)
TIP LEVEL SIGNAL
TIP POSITION SIGNAL
570
TIP DRIVING EQUIPMENT
540
TIP DETECTOR
550
SELECTION MECHANISM
560
SHIELDING CONTAINER

FIG. 6

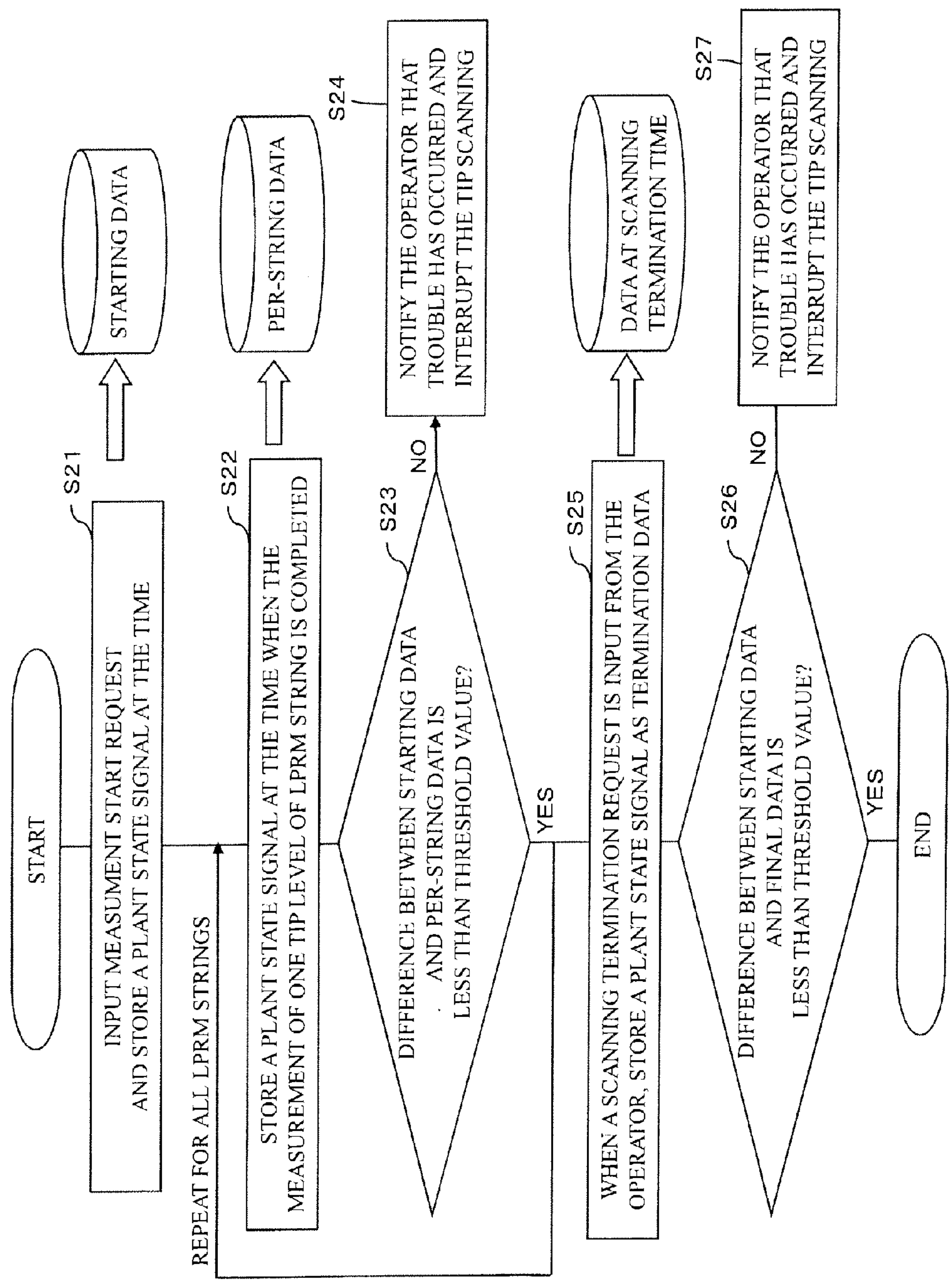

START
S21
INPUT MEASUMENT START REQUEST AND STORE A PLANT STATE SIGNAL AT THE TIME
STARTING DATA
REPEAT FOR ALL LPRM STRINGS
S22
STORE A PLANT STATE SIGNAL AT THE TIME WHEN THE MEASUREMENT OF ONE TIP LEVEL OF LPRM STRING IS COMPLETED
PER-STRING DATA
S23
DIFFERENCE BETWEEN STARTING DATA AND PER-STRING DATA IS LESS THAN THRESHOLD VALUE?
NO
S24
NOTIFY THE OPERATOR THAT TROUBLE HAS OCCURRED AND INTERRUPT THE TIP SCANNING
YES
S25
WHEN A SCANNING TERMINATION REQUEST IS INPUT FROM THE OPERATOR, STORE A PLANT STATE SIGNAL AS TERMINATION DATA
DATA AT SCANNING TERMINATION TIME
S26
DIFFERENCE BETWEEN STARTING DATA AND FINAL DATA IS LESS THAN THRESHOLD VALUE?
NO
S27
NOTIFY THE OPERATOR THAT TROUBLE HAS OCCURRED AND INTERRUPT THE TIP SCANNING
YES
END

FIG. 7

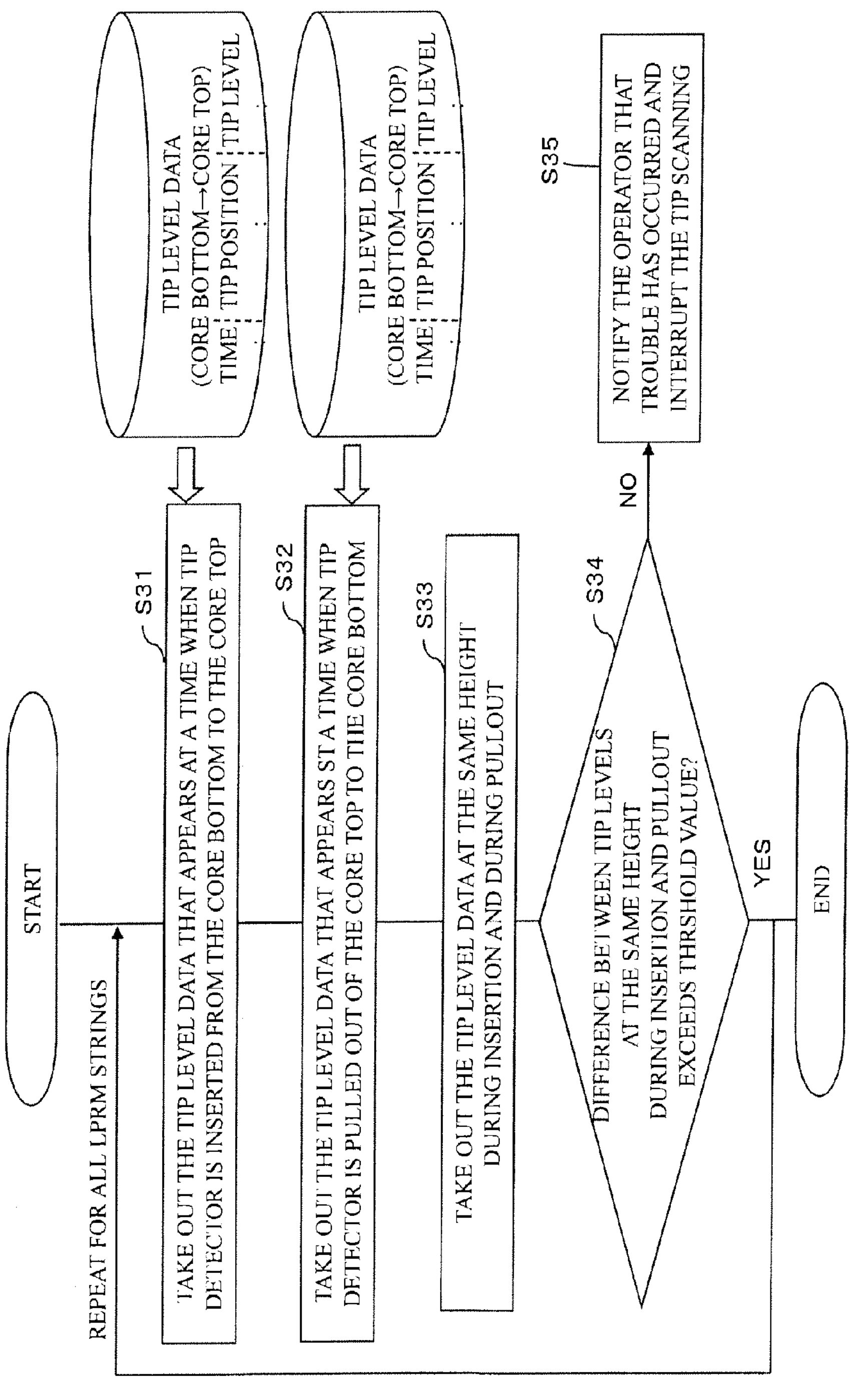

START
REPEAT FOR ALL LPRM STRINGS
S31
TAKE OUT THE TIP LEVEL DATA THAT APPEARS AT A TIME WHEN TIP DETECTOR IS INSERTED FROM THE CORE BOTTOM TO THE CORE TOP
TIP LEVEL DATA (CORE BOTTOM→CORE TOP)
TIME
TIP POSITION
TIP LEVEL
S32
TAKE OUT THE TIP LEVEL DATA THAT APPEARS AT A TIME WHEN TIP DETECTOR IS PULLED OUT OF THE CORE TOP TO THE CORE BOTTOM
TIP LEVEL DATA (CORE BOTTOM→CORE TOP)
TIME
TIP POSITION
TIP LEVEL
S33
TAKE OUT THE TIP LEVEL DATA AT THE SAME HEIGHT DURING INSERTION AND DURING PULLOUT
S34
DIFFERENCE BETWEEN TIP LEVELS AT THE SAME HEIGHT DURING INSERTION AND PULLOUT EXCEEDS THRSHOLD VALUE?
NO
YES
S35
NOTIFY THE OPERATOR THAT TROUBLE HAS OCCURRED AND INTERRUPT THE TIP SCANNING
END

FIG. 8

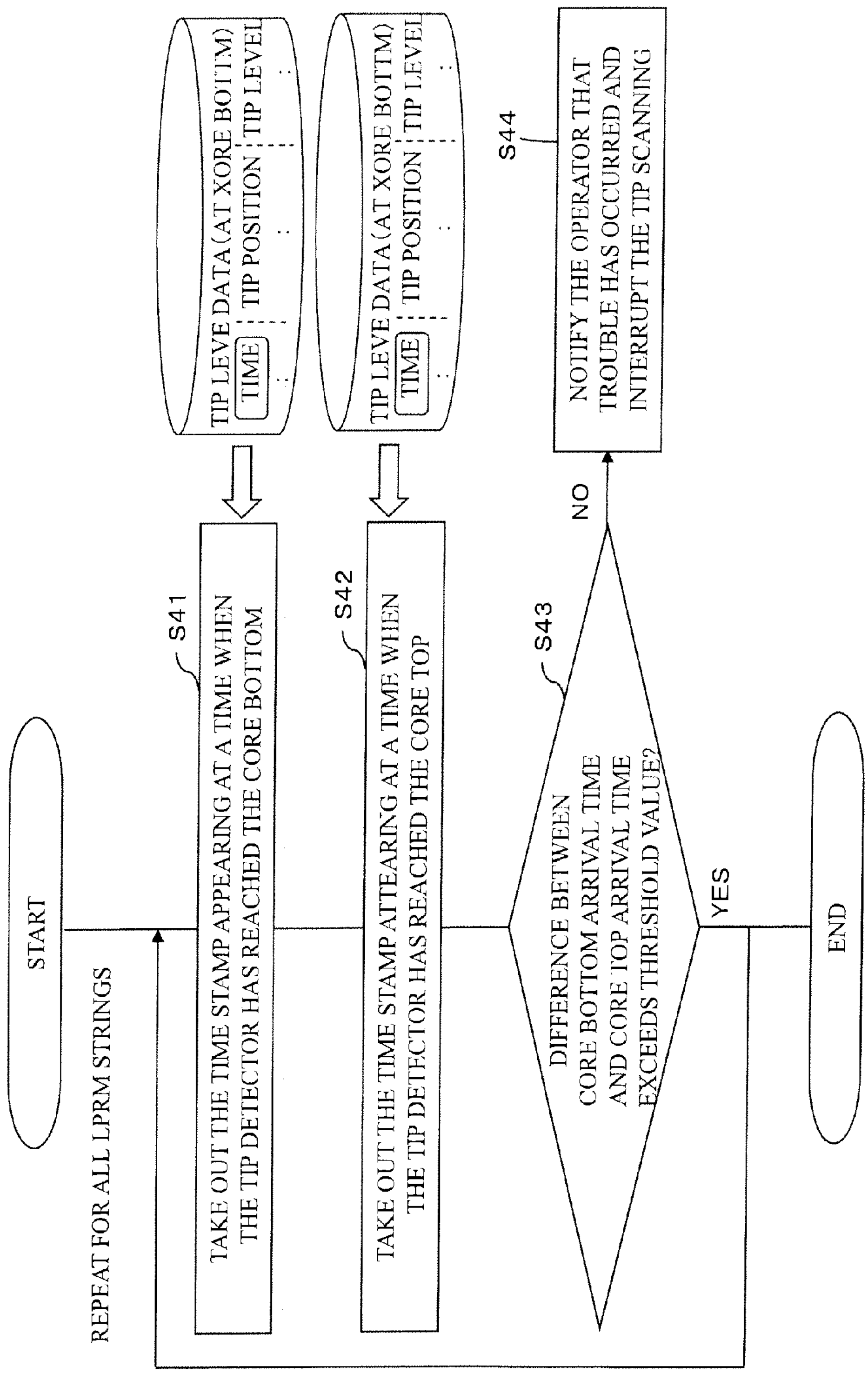

START
REPEAT FOR ALL LPRM STRINGS
S41
TAKE OUT THE TIME STAMP APPEARING AT A TIME WHEN THE TIP DETECTOR HAS REACHED THE CORE BOTTOM
TIP LEVE DATA (AT XORE BOTTM)
TIME
TIP POSITION
TIP LEVEL
S42
TAKE OUT THE TIME STAMP ATTEARING AT A TIME WHEN THE TIP DETECTOR HAS REACHED THE CORE TOP
TIP LEVE DATA (AT XORE BOTTM)
TIME
TIP POSITION
TIP LEVEL
S43
DIFFERENCE BETWEEN CORE BOTTOM ARRIVAL TIME AND CORE TOP ARRIVAL TIME EXCEEDS THRESHOLD VALUE?
NO
YES
S44
NOTIFY THE OPERATOR THAT TROUBLE HAS OCCURRED AND INTERRUPT THE TIP SCANNING
END

FIG. 9

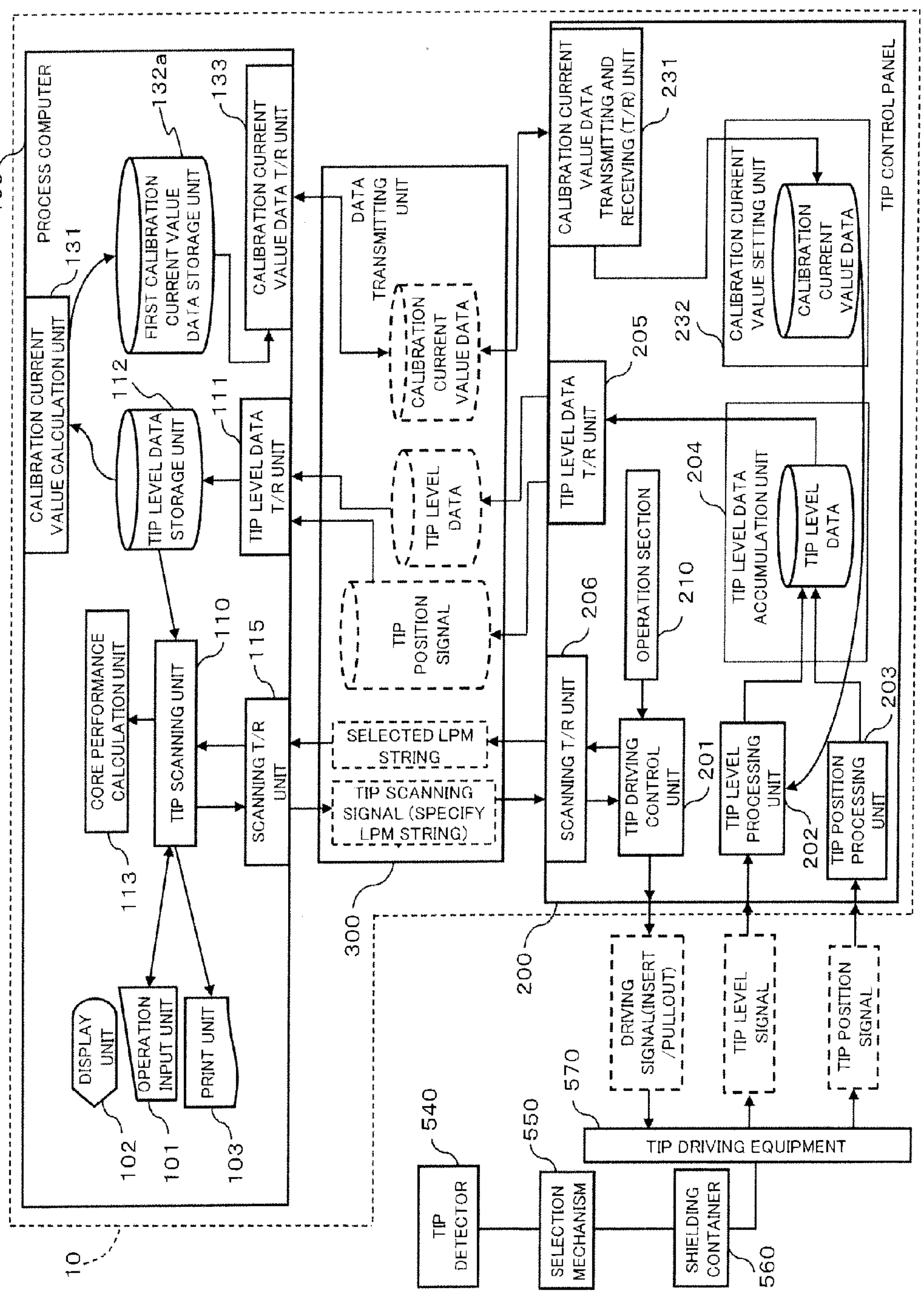

10
100
PROCESS COMPUTER
CALIBRATION CURRENT VALUE CALCULATION UNIT
131
FIRST CALIBRATION CURRENT VALUE DATA STORAGE UNIT
132a
CALIBRATION CURRENT VALUE DATA T/R UNIT
133
TIP LEVEL DATA STORAGE UNIT
112
TIP LEVEL DATA T/R UNIT
111
CORE PERFORMANCE CALCULATION UNIT
113
TIP SCANNING UNIT
110
SCANNING T/R UNIT
115
DISPLAY UNIT
102
OPERATION INPUT UNIT
101
PRINT UNIT
103
300
DATA TRANSMITTING UNIT
CALIBRATION CURRENT VALUE DATA
TIP LEVEL DATA
TIP POSITION SIGNAL
SELECTED LPM STRING
TIP SCANNING SIGNAL (SPECIFY LPM STRING)
200
TIP CONTROL PANEL
CALIBRATION CURRENT VALUE DATA TRANSMITTING AND RECEIVING (T/R) UNIT
231
CALIBRATION CURRENT VALUE SETTING UNIT
232
CALIBRATION CURRENT VALUE DATA
TIP LEVEL DATA T/R UNIT
205
TIP LEVEL DATA ACCUMULATION UNIT
204
TIP LEVEL DATA
OPERATION SECTION
210
SCANNING T/R UNIT
206
TIP DRIVING CONTROL UNIT
201
TIP LEVEL PROCESSING UNIT
202
TIP POSITION PROCESSING UNIT
203
DRIVING SIGNAL(INSERT /PULLOUT)
TIP LEVEL SIGNAL
TIP POSITION SIGNAL
570
TIP DRIVING EQUIPMENT
540
TIP DETECTOR
550
SELECTION MECHANISM
SHIELDING CONTAINER
560

FIG.10

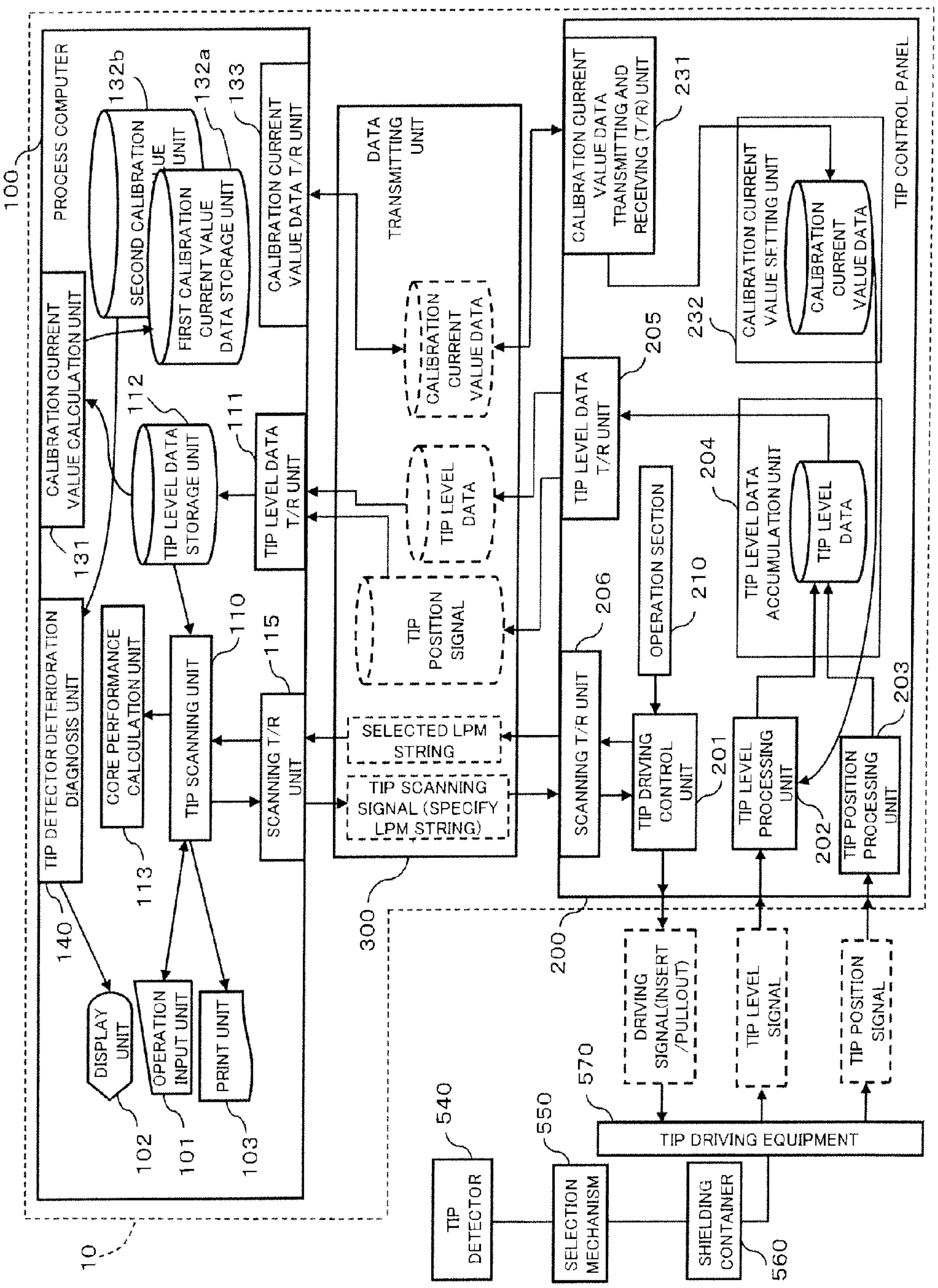

100
PROCESS COMPUTER
132b
SECOND CALIBRATION CURRENT VALUE DATA STORAGE UNIT
132a
FIRST CALIBRATION CURRENT VALUE DATA STORAGE UNIT
133
CALIBRATION CURRENT VALUE DATA T/R UNIT
CALIBRATION CURRENT VALUE CALCULATION UNIT
131
112
TIP LEVEL DATA STORAGE UNIT
111
TIP LEVEL DATA T/R UNIT
TIP DETECTOR DETERIORATION DIAGNOSIS UNIT
140
CORE PERFORMANCE CALCULATION UNIT
113
110
TIP SCANNING UNIT
115
SCANNING T/R UNIT
DISPLAY UNIT
102
OPERATION INPUT UNIT
101
PRINT UNIT
103
10
DATA TRANSMITTING UNIT
CALIBRATION CURRENT VALUE DATA
TIP LEVEL DATA
TIP POSITION SIGNAL
SELECTED LPM STRING
TIP SCANNING SIGNAL (SPECIFY LPM STRING)
300
CALIBRATION CURRENT VALUE DATA TRANSMITTING AND RECEIVING (T/R) UNIT
231
TIP CONTROL PANEL
CALIBRATION CURRENT VALUE SETTING UNIT
CALIBRATION CURRENT VALUE DATA
232
205
TIP LEVEL DATA T/R UNIT
OPERATION SECTION
210
204
TIP LEVEL DATA ACCUMULATION UNIT
TIP LEVEL DATA
206
SCANNING T/R UNIT
TIP DRIVING CONTROL UNIT
201
TIP LEVEL PROCESSING UNIT
202
TIP POSITION PROCESSING UNIT
203
200
DRIVING SIGNAL(INSERT /PULLOUT)
TIP LEVEL SIGNAL
TIP POSITION SIGNAL
570
TIP DRIVING EQUIPMENT
540
TIP DETECTOR
550
SELECTION MECHANISM
SHIELDING CONTAINER
560

FIG.11

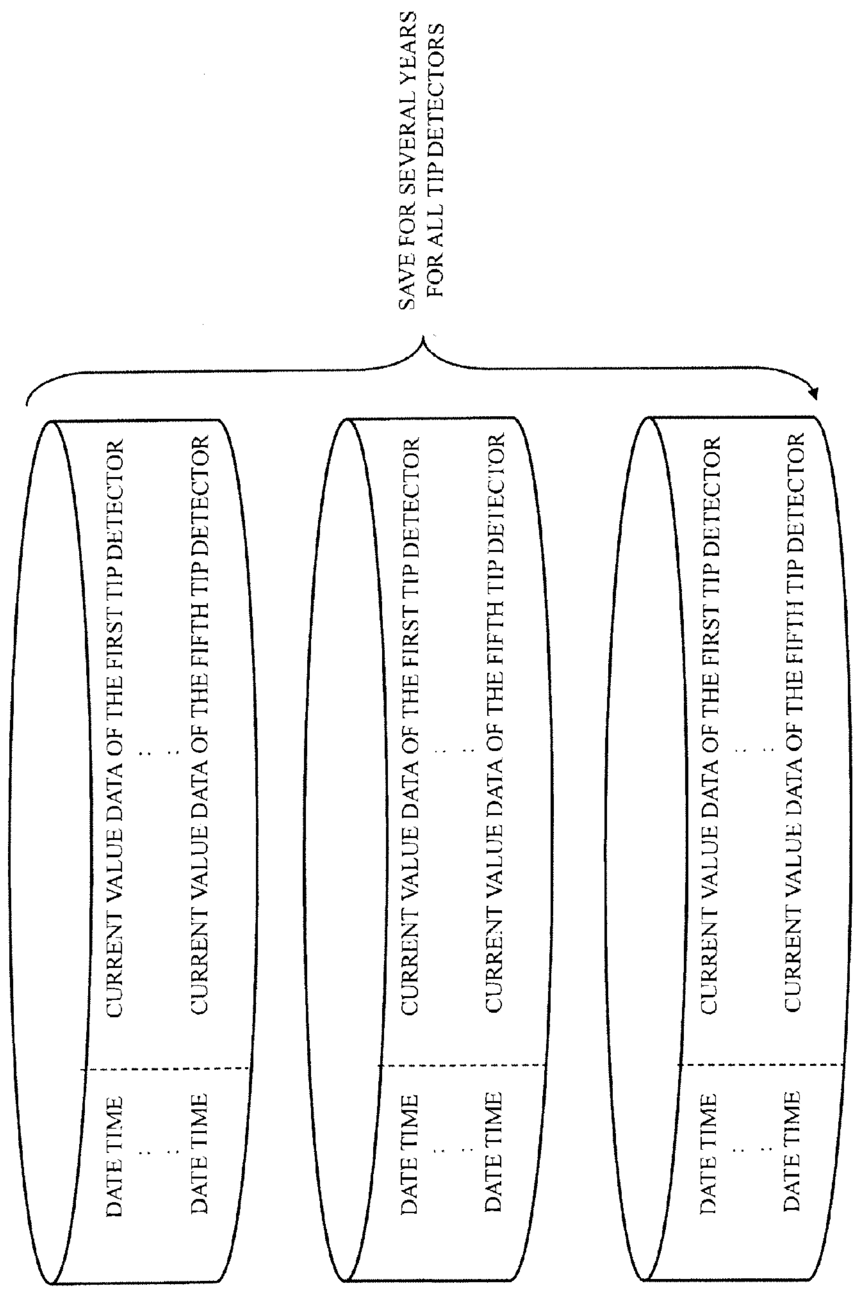

SAVE FOR SEVERAL YEARS
FOR ALL TIP DETECTORS
DATE TIME
DATE TIME
CURRENT VALUE DATA OF THE FIRST TIP DETECTOR
CURRENT VALUE DATA OF THE FIFTH TIP DETECTOR
DATE TIME
DATE TIME
CURRENT VALUE DATA OF THE FIRST TIP DETECTOR
CURRENT VALUE DATA OF THE FIFTH TIP DETECTOR
DATE TIME
DATE TIME
CURRENT VALUE DATA OF THE FIRST TIP DETECTOR
CURRENT VALUE DATA OF THE FIFTH TIP DETECTOR

FIG.12

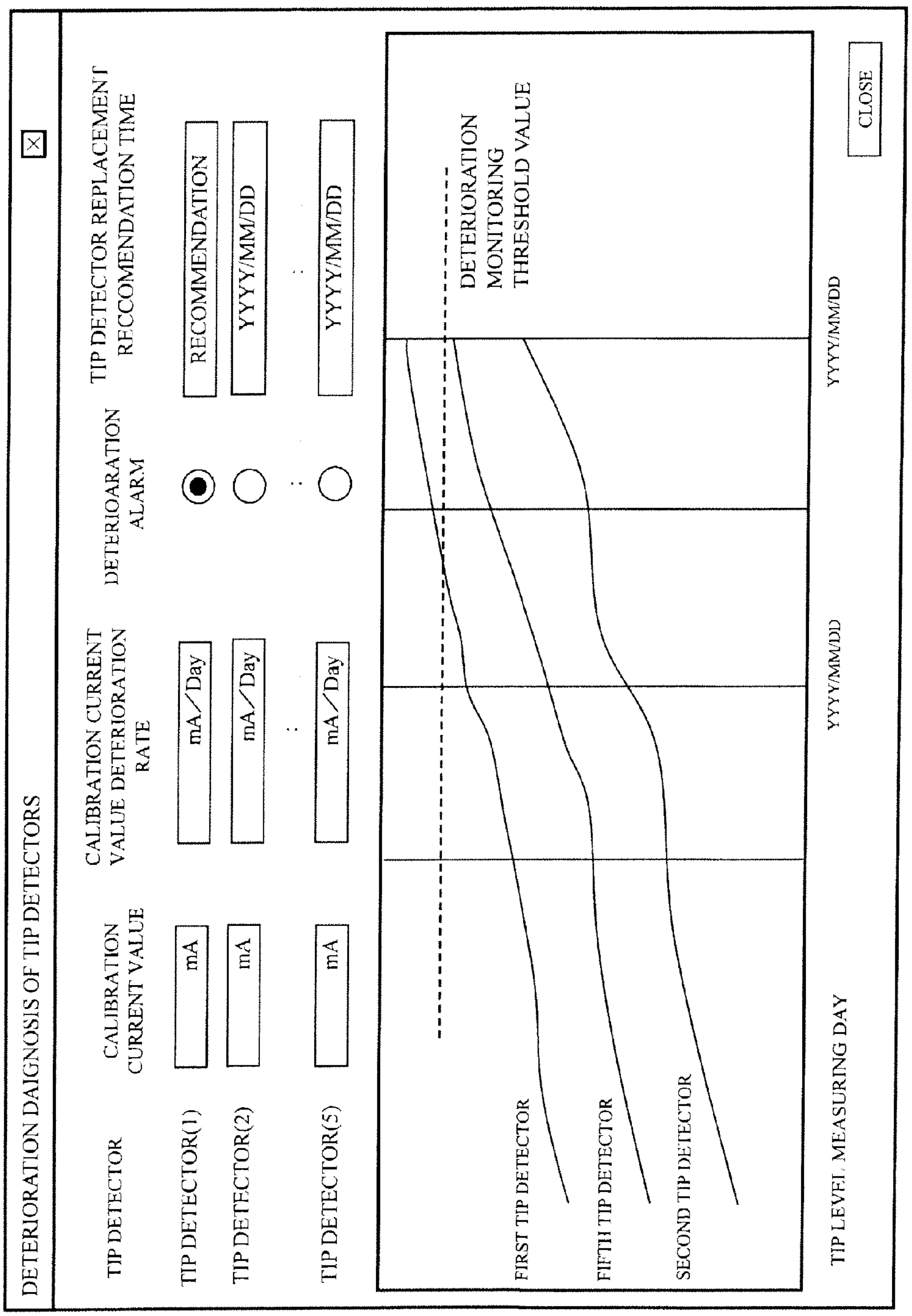

DETERIORATION DAIGNOSIS OF TIP DETECTORS
TIP DETECTOR
CALIBRATION CURRENT VALUE
CALIBRATION CURRENT VALUE DETERIORATION RATE
DETERIOARATION ALARM
TIP DETECTOR REPLACEMENT RECCOMENDATION TIME
TIP DETECTOR(1)
mA
mA/Day
RECOMMENDATION
TIP DETECTOR(2)
mA
mA/Day
YYYY/MM/DD
TIP DETECTOR(5)
mA
mA/Day
YYYY/MM/DD
DETERIORATION MONITORING THRESHOLD VALUE
FIRST TIP DETECTOR
FIFTH TIP DETECTOR
SECOND TIP DETECTOR
TIP LEVEL MEASURING DAY
YYYY/MM/DD
YYYY/MM/DD
CLOSE

FIG.13

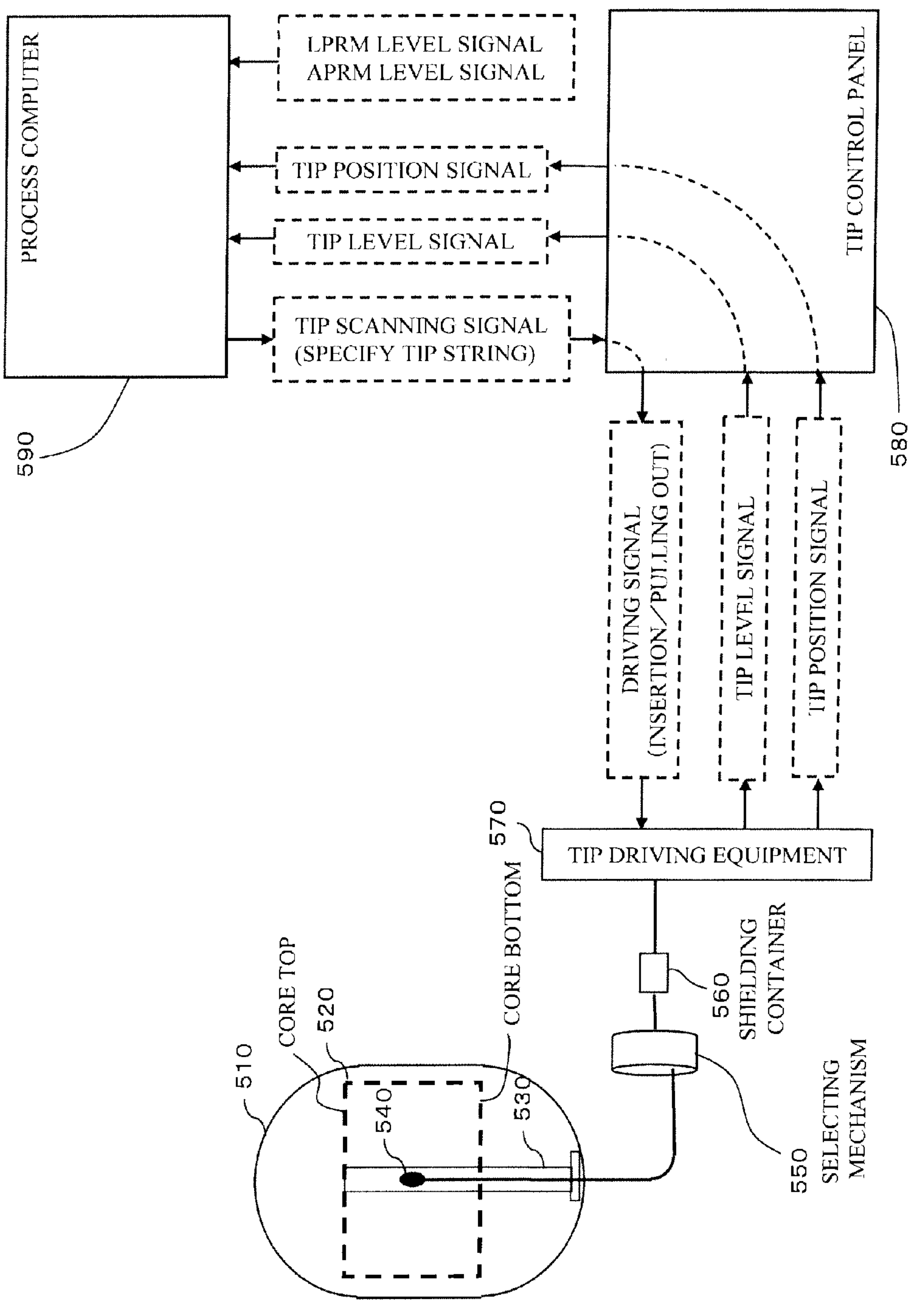
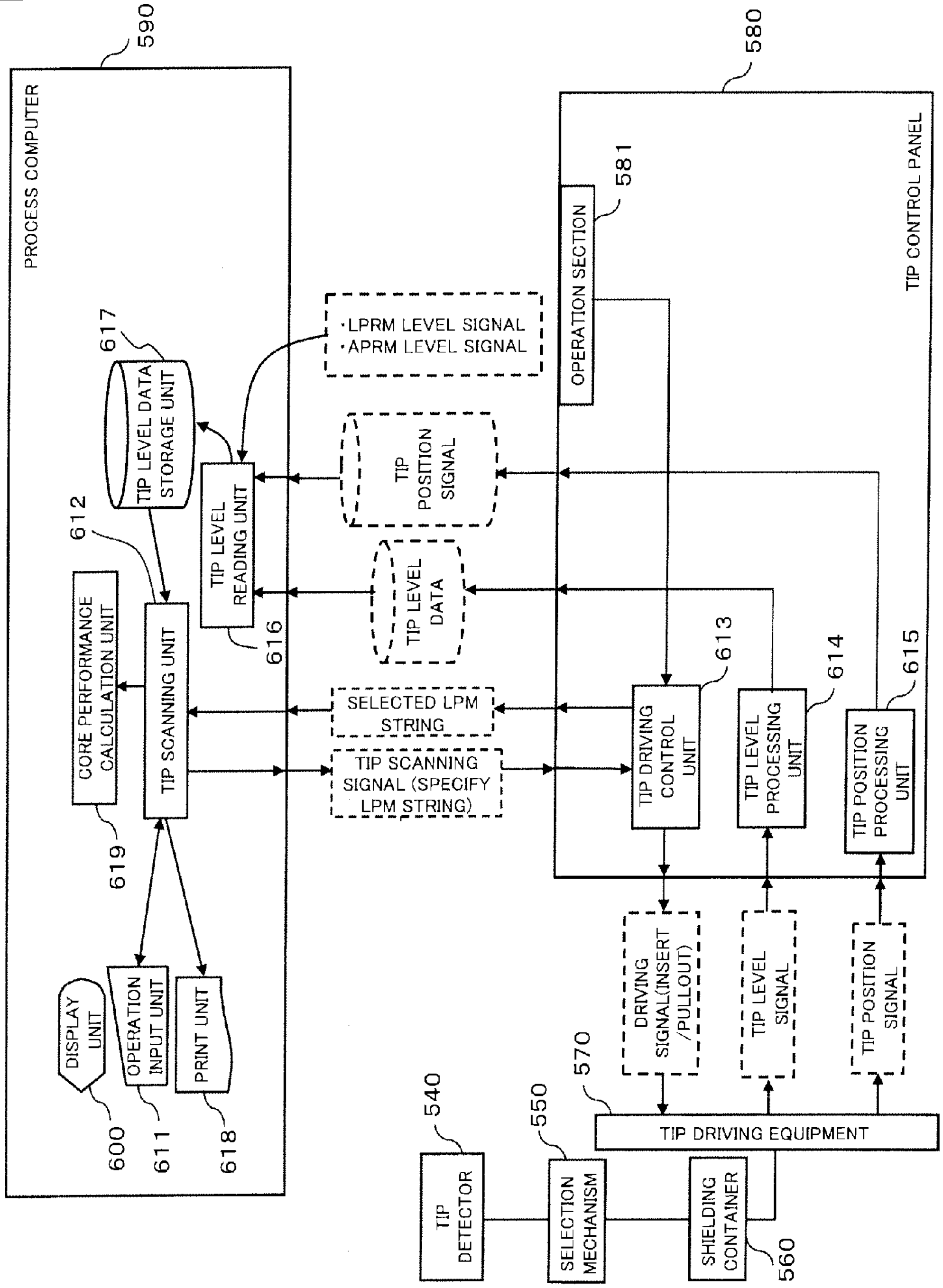
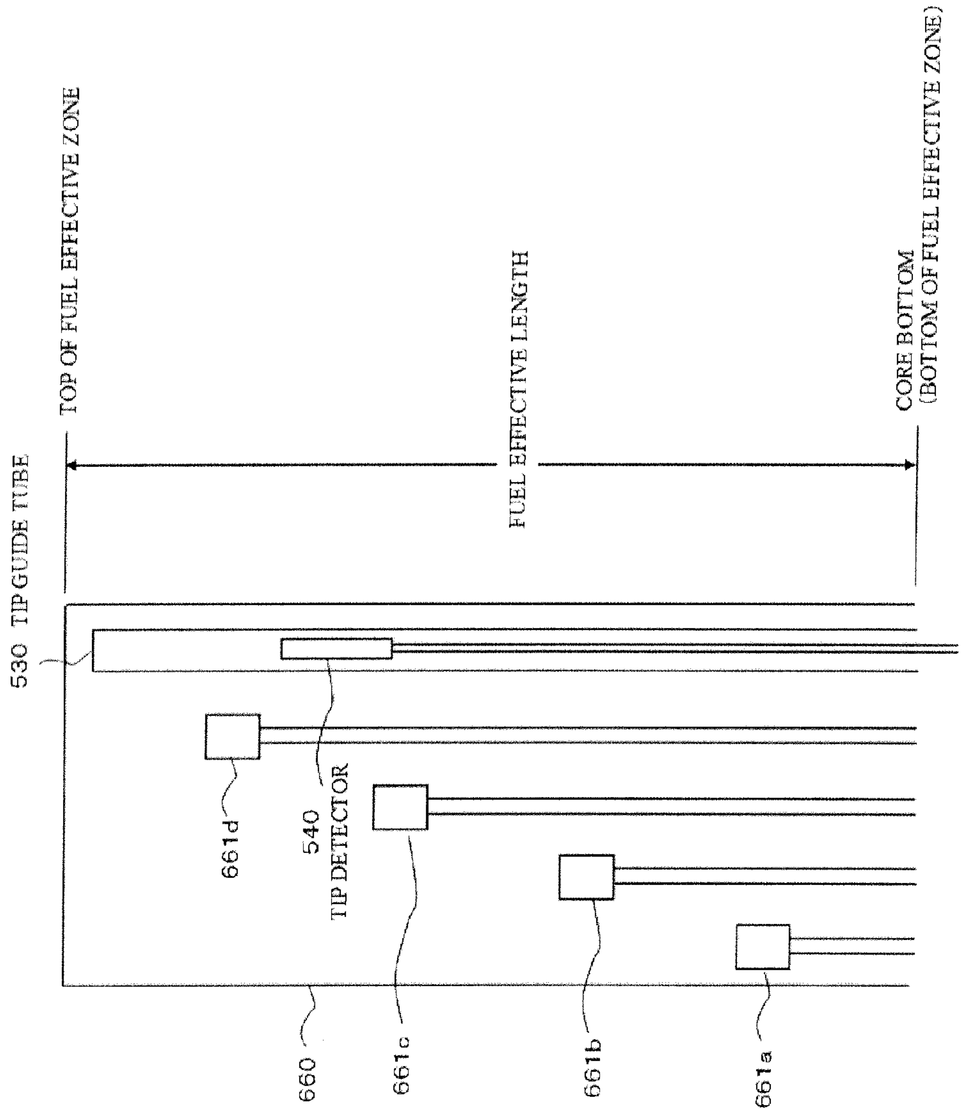

PROCESS COMPUTER
LPRM LEVEL SIGNAL
APRM LEVEL SIGNAL
TIP POSITION SIGNAL
TIP LEVEL SIGNAL
TIP SCANNING SIGNAL
(SPECIFY TIP STRING)
TIP CONTROL PANEL
590
580
DRIVING SIGNAL
(INSERTION/PULLING OUT)
TIP LEVEL SIGNAL
TIP POSITION SIGNAL
570
TIP DRIVING EQUIPMENT
560
SHIELDING
CONTAINER
550
SELECTING
MECHANISM
510
CORE TOP
520
CORE BOTTOM
530
540

FIG.14

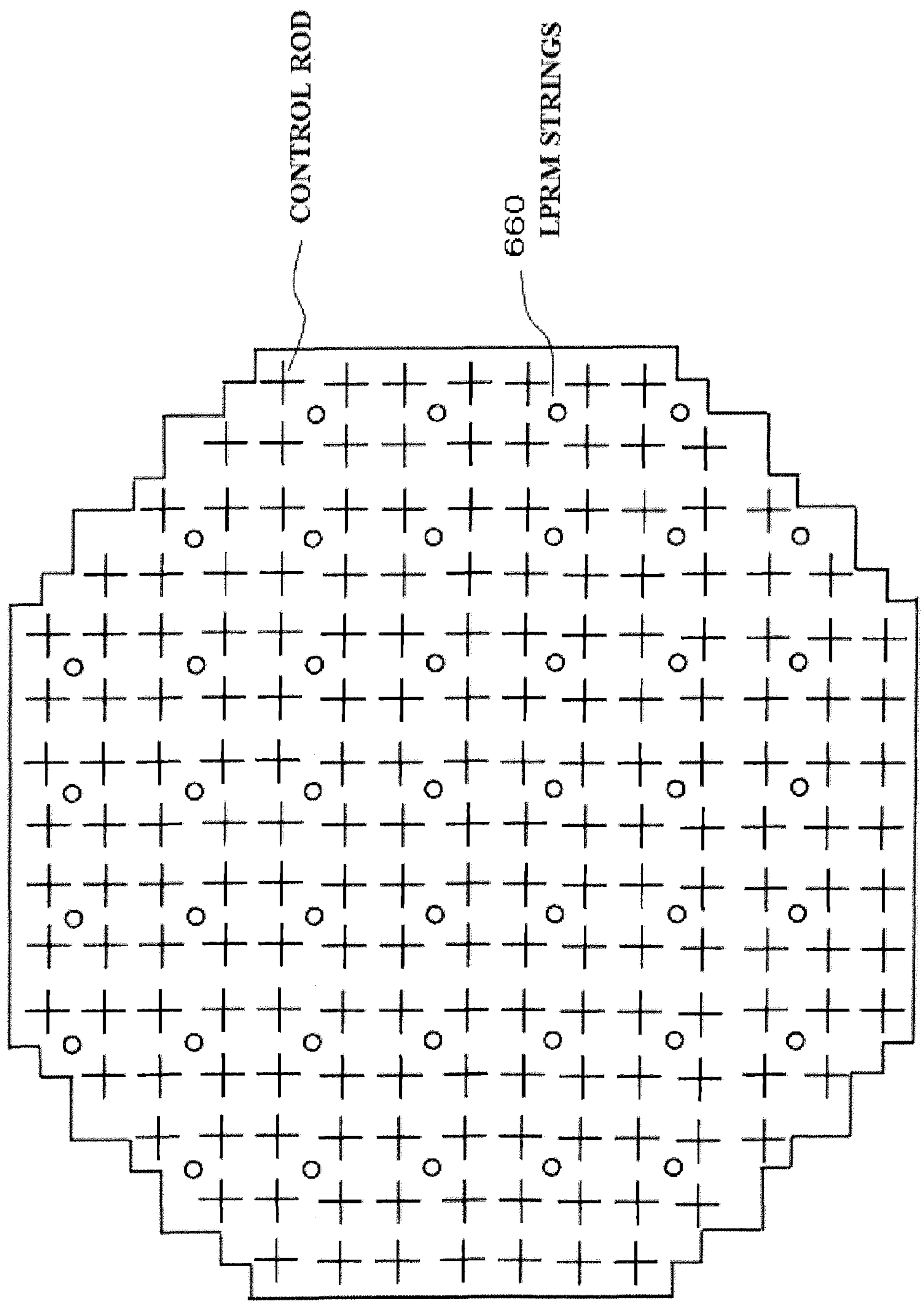

590
PROCESS COMPUTER
617
TIP LEVEL DATA STORAGE UNIT
612
TIP LEVEL READING UNIT
616
CORE PERFORMANCE CALCULATION UNIT
TIP SCANNING UNIT
619
DISPLAY UNIT
OPERATION INPUT UNIT
PRINT UNIT
600
611
618
•LPRM LEVEL SIGNAL
•APRM LEVEL SIGNAL
TIP POSITION SIGNAL
TIP LEVEL DATA
SELECTED LPM STRING
TIP SCANNING SIGNAL (SPECIFY LPM STRING)
580
TIP CONTROL PANEL
581
OPERATION SECTION
613
TIP DRIVING CONTROL UNIT
614
TIP LEVEL PROCESSING UNIT
615
TIP POSITION PROCESSING UNIT
DRIVING SIGNAL(INSERT /PULLOUT)
TIP LEVEL SIGNAL
TIP POSITION SIGNAL
570
TIP DRIVING EQUIPMENT
540
TIP DETECTOR
550
SELECTION MECHANISM
SHIELDING CONTAINER
560



TOP OF FUEL EFFECTIVE ZONE
FUEL EFFECTIVE LENGTH
CORE BOTTOM
(BOTTOM OF FUEL EFFECTIVE ZONE)
530 TIP GUIDE TUBE
540
TIP DETECTOR
661d
661c
661b
661a
660

FIG.15

FIG.16



TIP SYSTEM AND TIP MONITORING CONTROL EQUIPMENT

CROSS REFERENCES TO RELATED APPLICATIONS

This application is based upon and claims the benefits of priority from the prior Japanese Patent Application No. 2011-134699, filed in the Japanese Patent Office on Jun. 17, 2011, the entire content of which is incorporated herein by reference.

FIELD

The present invention relates to a TIP monitoring control equipment, which is one portion of an in-reactor nuclear instrumentation system, and a TIP system containing the TIP monitoring control equipment.

BACKGROUND

A mobile in-core instrumentation equipment (referred to as "TIP (Traversing Incore Probe) system," hereinafter), which is one portion of an in-reactor nuclear instrumentation system in a boiling water reactor (BWR) nuclear power plant, is designed to measure a neutron flux level by moving a detector in an axial direction in a nuclear reactor when the nuclear power plant is in operation; obtain a reactor power distribution at each level of height in a direction of a core axis; and provide data that are used as a basis for calculating a reactor power distribution.

FIG. **13** is a block diagram showing an overall configuration of a conventional TIP system, as well as a nuclear reactor.

The TIP system transfers a TIP detector **540** into a plurality of TIP guide tubes **53**, which are disposed in a reactor core **520** of a nuclear reactor **510**. When the TIP detector **540** is pulled out from the top to the bottom of the reactor core **520**, the TIP system generates a TIP position signal corresponding to a travel distance. In synchronization with the TIP position signal, the TIP system reads a TIP level signal, an LPRM level signal from a local power range monitor (referred to as "LPRM (Local Power Range Monitor)", hereinafter), and an APRM level signal from an average power range monitor (referred to as "APRM (Average Power Range Monitor)", hereinafter) to measure a neutron flux distribution of an in-core axial direction.

A process computer **590** and a TIP control panel **580** work together with each other and output a driving signal (insertion/pull-out signal for the detector) to a TIP driving equipment **570**. Thereby, the TIP detector **540** is transferred.

In the TIP detector **540**, the sensitivity thereof becomes attenuated by neutron radiation. Therefore, the TIP detector **540** is inserted into the nuclear reactor only when measurement takes place. When no measurement takes place, the TIP detector **540** is stored in a shielding container **560** outside of the nuclear reactor, thereby minimizing neutron radiation and preventing the attenuation of the detector's sensitivity.

FIG. **14** is a block diagram showing the configuration of a conventional TIP system, as well as signal processing.

Measuring a neutron flux level by the TIP system is performed in the following manner.

In a process computer **590**, a display unit **600** and an operation input unit **611** are placed. An operator uses the above units to specify a TIP scanning signal (TIP scanning start/interrupt signal) and a TIP guide tube **530** (LPRM string) for which a neutron flux level is measured.

A signal input by the operator is processed by a TIP scanning unit **612** of the process computer **590**, and then transferred to a TIP driving control unit **613** of a TIP control panel **580**.

Moreover, on the TIP control panel **580**, a TIP control panel operation section **581** is mounted. The operator is able to carry out an operation of making a driving request and a request of pull-out/insertion of the detector through a switch on the TIP control panel operation section **581**. A TIP scanning signal from the process computer **590** is input into the TIP driving control unit **613**, which outputs a driving signal (insertion/pull-out signal for the detector) to the TIP driving equipment **570**.

Then, the TIP driving equipment **570** drives the TIP detector **540** in a direction corresponding to the driving signal.

Meanwhile, the neutron flux level measured by the TIP detector **540** is input, as a TIP level signal, into a TIP level reading unit **616** of the process computer **590** via a TIP level processing unit **614** of the TIP control panel **580**.

Moreover, the height from the core top to core bottom of the TIP detector **540** is input, as a TIP position signal that is generated while the TIP detector **540** moves from the core top to the core bottom, into the TIP level reading unit **616** of the process computer **590** via a TIP position processing unit **615** of the TIP control panel **580**.

The TIP level reading unit **616** of the process computer **590** reads a TIP level signal at a timing when the TIP position signal is turned ON (at a distance interval of an inch). Moreover, the TIP level reading unit **616** reads an LPRM level signal at timings of the core top and the core bottom, and an APRM level signal at timings of the core top, the core center and the core bottom; the signals are then stored in a TIP level data storage unit **617** of the process computer **590**.

Then, the TIP data stored in the TIP level data storage unit **617** of the process computer **590** are displayed on the display unit **600** by the TIP scanning unit **612**, and a log thereof is printed on a print unit **618**. Moreover, the TIP data are transferred to a core performance calculation unit **619**, where the TIP data are used as a basis for calculating a reactor power distribution.

FIG. **15** is a conceptual diagram of an axial-direction position of an assembly (referred to as "LPRM string", hereinafter) of local power range monitors (referred to as "LPRM", hereinafter).

LPRM strings are provided in the reactor core. Each of the LPRM strings contains one TIP guide tube **530** therein. Along an axial direction thereof, for each of the LPRM strings, four LPRM detectors "A", "B", "C" and "D" **661***a*, **661***b*, **661***c* and **661***d*, respectively are positioned and fixed.

FIG. **16** is a conceptual diagram of the arrangement of LPRM strings in the reactor core.

In the reactor core, a large number of LPRM strings are disposed. In the example of FIG. **16**, the LPRM strings **660** are divided into five groups.

As for the TIP detectors **540**, all the LPRM strings **600** are not covered by one TIP detector **540**. In response to the above, five TIP detectors **540**, "A", "B", "C", "D" and "E", are provided. Each of the TIP detectors **540** sequentially runs in about 10 LPRM strings.

An LPRM string **660** into which a TIP detector **540** is inserted is selected by rotating a rotating cylinder of a selection mechanism **550** shown in FIG. **13**. At this time, selection is not made in such a way that a plurality of TIP detectors **540** are inserted into the same LPRM string **660**.

Examples of related prior art documents are as follows: Jpn. Pat. Apple. Publication No. H05-11278, Jpn. Pat. Appln. Laid-Open Publication No. 2000-28782, Jpn. Pat. Appln.

Laid-Open Publication No. 2006-145417, and Jpn. Pat. Appln. Laid-Open Publication No. H05-312991.

According to the conventional TIP system, the TIP control panel is an analog circuit. Therefore, data cannot be accumulated, and a TIP level signal and a TIP position signal are output from the TIP control panel to the process computer without being processed or stored.

Then, in the process computer, what is performed is a process of reading a TIP level signal (analog signal), which appears at a time when a TIP position signal (pulse signal) is turned ON, synchronously as a TIP level at a height thereof. However, because of hardware constraints of the process computer, the ON time of the pulse signal requires about 100 milliseconds.

Therefore, the driving speed of the TIP detector cannot be increased over 3 inches per second, which is why a reduction in plant start-up time cannot be achieved in completing the measurement of the TIP levels of the entire reactor core. Thus, the measurement is completed for about 15 to 30 minutes.

Another problem is that, due to the transfer lag of a signal or the delay of a timing at which the process computer detects that the pulse signal is ON, the accuracy of reading the TIP level data is not sufficient.

Furthermore, as for the data that serve as a basis for calculating the reactor power distribution, in synchronization with a TIP position signal, an LPRM level signal and an APRM level signal need to be input. However, the TIP control panel exists independently of an LPRM panel and an APRM panel. Therefore, the problem is that it is not possible to input an LPRM level signal and an APRM level signal in synchronization with a TIP position signal on the TIP control panel.

The TIP level data that are read into the process computer are used as basic data, which are used to improve the accuracy of power-distribution calculation in a process of calculating the reactor core's performance. However, in a conventional TIP system, it takes about one to two hours to measure the TIP levels of all the LPRM strings in the reactor core. Accordingly, during a process of measuring the TIP levels, there are changes in the states of the plant, which, for example, include a reactor thermal power, a core flow rate, a control-rod position, and the like. Thus, it is not possible to input TIP level data that accurately reflect the current power distribution. The problem is that the accuracy of calculating the reactor power distribution can deteriorate.

In the conventional TIP system, on the TIP control panel, a TIP level at a common guide tube (common string) is plotted by a mechanical pen recorder. From a chart of the pen recorder, the TIP level is read visually; the values of calibration current of the TIP detectors are adjusted (Gain adjustment) so as to have the same TIP level between each TIP detector at the common string. However, the accuracy of reading the TIP levels visually from the chart of the mechanical pen recorder is not sufficient. Another problem is that it takes a lot of time and effort for an operator to manually adjust the values of calibration current.

Moreover, in the conventional TIP system, the value of calibration current on the TIP control panel is confirmed before the deterioration of a TIP detector is assessed. Therefore, the problem is that it is difficult to determine the long-term trend of TIP deterioration, and to plan a replacement time of the TIP detector accurately.

Furthermore, in the conventional TIP system, between the TIP control panel and the process computer, as for each TIP, I/O cables are required for a TIP level signal, a TIP position signal, and the information about a selected LPRM string, i.e. a channel number, a contact signal associated with whether or not a TIP detector exists at a specific position such as the core bottom or top, or any other signal. A total of, for example, 135 cables are required for five TIP detectors. If the distance between the TIP control panel and the process computer is 100 m, the total length of the cables amounts to about 13 km. In this manner, large amount of cables are required.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing the configuration of a first embodiment of a TIP system according to the present invention;

FIG. **2** is a flowchart showing the flow of a process by a TIP level data accumulation unit according to the first embodiment;

FIG. **3** is an explanatory diagram showing the configuration of TIP level data according to the first embodiment;

FIG. **4** is a flowchart showing the flow of a process of reading an LPRM level signal and an APRM level signal of a TIP level data transmitting and receiving unit according to the first embodiment;

FIG. **5** is a block diagram showing the configuration of a second embodiment of a TIP system according to the present invention;

FIG. **6** is a flowchart showing the flow of process of monitoring the state of a plant in which a TIP level is being measured, or monitoring at a measurement start/end timing and monitoring at each LPRM string, according to the second embodiment;

FIG. **7** is a flowchart showing the flow of a process of monitoring the state of a plant in which a TIP level is being measured, or monitoring of a TIP level, according to the second embodiment;

FIG. **8** is a flowchart showing the flow of a process of monitoring the state of a plant in which a TIP level is being measured, or monitoring of driving time of a TIP detector according to the second embodiment;

FIG. **9** is a block diagram showing the configuration of a third embodiment of a TIP system according to the present invention;

FIG. **10** is a block diagram showing the configuration of a fourth embodiment of a TIP system according to the present invention;

FIG. **11** is an explanatory diagram showing the configuration of a calibration current value data storage unit according to the fourth embodiment;

FIG. **12** is an explanatory diagram showing an example of a deterioration assessment screen of a TIP detector according to the fourth embodiment;

FIG. **13** is a block diagram showing the overall configuration of a conventional TIP system, as well as a nuclear reactor;

FIG. **14** is a block diagram showing the configuration of a conventional TIP system, as well as signal processing;

FIG. **15** is an explanatory diagram showing the concept of axial-direction positions of LPRM strings (an LPRM assembly and a TIP guide tube); and

FIG. **16** is an explanatory diagram showing the concept of an in-core arrangement of LPRM strings.

DETAILED DESCRIPTION

In view of the above-identified problem, the object of the present invention is to make high-speed running possible, while ensuring the same level of accuracy as the conventional one, without being affected by a driving time of a TIP detector, a transfer lag of a signal, a delay of a timing at which a process computer detects that a pulse signal is ON, or the like, as well as to reduce the amount of cables.

According to an embodiment, there is provided a TIP monitoring control equipment comprising: a process computer, a TIP control panel, and a data transmission unit, wherein the process computer includes: a TIP scanning unit that receives a TIP scanning request instruction and outputs a TIP scanning signal, a first TIP level data transmitting and receiving unit to which an LPRM level signal, an APRM level signal and TIP level data accumulated in the TIP control panel are input in synchronization with a TIP position signal, and a TIP level data storage unit that stores the TIP level data; the TIP control panel includes: a TIP driving control unit that accepts the TIP scanning signal as an input and outputs a driving signal to a TIP driving equipment, a TIP level processing unit to which a TIP level signal from the TIP driving equipment is input, a TIP position processing unit to which a TIP position signal from the TIP driving equipment is input, a TIP level data accumulation unit to which a TIP level signal is input in synchronization with a TIP position signal and in which TIP level data are accumulated, and a second TIP level data transmitting and receiving unit that transmits TIP level data accumulated in the TIP level data accumulation unit to the process computer via the data transmission unit.

According to another embodiment, there is provided a TIP system comprising: a plurality of TIP detectors, a selection mechanism that sequentially selects one of a plurality of TIP guide tubes for each of the TIP detectors, a shielded container in which the TIP detectors are stored in any time other than a measurement period of the TIP detectors, a TIP driving equipment that drives the insertion and pullout of the TIP detectors into the TIP guide tubes, and a TIP monitoring control equipment, wherein the TIP monitoring control equipment has: a process computer, a TIP control panel, and a data transmission unit, the process computer including: a TIP scanning unit that receives a TIP scanning request instruction and outputs a TIP scanning signal, a first TIP level data transmitting and receiving unit to which an LPRM level signal, an APRM level signal and TIP level data accumulated in the TIP control panel are input in synchronization with a TIP position signal, and a TIP level data storage unit that stores the TIP level data; the TIP control panel including: a TIP driving control unit that accepts the TIP scanning signal as an input and outputs a driving signal to the TIP driving equipment, a TIP level processing unit to which a TIP level signal from the TIP driving equipment is input, a TIP position processing unit to which a TIP position signal from the TIP driving equipment is input, a TIP level data accumulation unit to which a TIP level signal is input in synchronization with a TIP position signal and in which TIP level data are accumulated, and a second TIP level data transmitting and receiving unit that transmits TIP level data accumulated in the TIP level data accumulation unit to the process computer via the data transmission unit, wherein the second TIP level data transmitting and receiving unit transmits TIP level data accumulated in the TIP level data accumulation unit to the process computer.

Hereinafter, with reference to the accompanying drawings, embodiments of a TIP system of the present invention will be described. The same or similar portions are represented by the same reference symbols, and the same descriptions will not be repeated herein.

[First Embodiment]

FIG. **1** is a block diagram showing the configuration of a first embodiment of a TIP system of the present invention.

As shown in FIG. **1**, a TIP system of the present embodiment includes a TIP detector **540**, a selection mechanism **550**, a shielding container **560**, a TIP driving equipment **570**, and a TIP monitoring control equipment **10**.

The TIP monitoring control equipment **10** includes a process computer **100**, a TIP control panel **200**, and a data transmitting unit **300**.

First, the process computer **100** will be described.

The process computer **100** includes an operation input unit **101**, a display unit **102**, a print unit **103**, a TIP scanning unit **110**, a TIP level data transmitting and receiving (T/R) unit **111**, and a TIP level data storage unit **112**.

The operation input unit **101** is a portion where an operator carries out an interactive operation. The TIP scanning unit **110** performs a TIP scanning process in response to a TIP scanning request from the operator, and outputs a TIP scanning signal to the TIP control panel **200**.

The operator carries out an interactive operation through the operation input unit **101** of the process computer **100**. In response to a TIP scanning request from the operator, the TIP scanning unit **110** performs a TIP scanning process.

TIP level data accumulated in the TIP control panel **200** and a current TIP position signal are input to the TIP level data T/R unit **111** via the data transmitting unit **300**.

Moreover, an LPRM level signal and an APRM level signal are also input to the TIP level data T/R unit **111** in synchronization with a TIP position signal, and are stored in the TIP level data storage unit **112**.

The following describes the TIP control panel **200**.

The TIP control panel **200** includes a TIP driving control unit **201**, a TIP level processing unit **202**, a TIP position processing unit **203**, a TIP level data accumulation unit **204**, and a TIP level data transmitting and receiving (T/R) unit **205**.

A TIP scanning signal from the process computer **100** is input to the TIP driving control unit **201**. The TIP driving control unit **201** outputs a driving signal to the TIP driving equipment **570**.

To the TIP level processing unit **202**, a TIP level signal from the TIP driving equipment **570** is input. The TIP level processing unit **202** converts an analog signal to a digital signal, and outputs the digital signal to the TIP level data accumulation unit **204** in which the digital signal is stored.

To the TIP position processing unit **203**, a TIP position signal from the TIP driving equipment **570** is input. The TIP position processing unit **203** converts an analog signal to a digital signal, and outputs the digital signal to the TIP level data accumulation unit **204** in which the digital signal is stored.

To the TIP level data accumulation unit **204**, the TIP position signal is input, and the TIP level signal is also input in synchronization with the TIP position signal. In the TIP level data accumulation unit **204**, TIP position data and TIP level data are accumulated as digital signals.

The TIP level data accumulation unit **204** outputs each piece of the above information, which is held as digital information, to the TIP level data T/R unit **205**.

In conjunction with the TIP level data T/R unit **111**, the TIP level data T/R unit **205** enables each set of the above data output from the TIP level data accumulation unit **204** to be transmitted by the data transmitting unit **300** having a network configuration, such as Ethernet (Registered Trademark).

Although not shown in the diagram, besides the above TIP position signal and TIP level signal, from the TIP driving equipment **570** to the TIP control panel **200**, the information about a selected LPRM string, i.e. a channel number, a contact signal associated with whether or not a TIP detector exists at a specific position such as the core bottom or top, or any other signal, is output. The above signals are received by the TIP driving control unit **201**, and are then transmitted by a network via the data transmitting unit **300** between the a scanning transmitting and receiving (T/R) unit **206** and a scanning transmitting and receiving (T/R) unit **115**.

The following describes the data transmitting unit **300**.

The data transmitting unit **300** has a signal transmission function of receiving the TIP level data and TIP position signal output from the TIP level data T/R unit **205** of the TIP control panel **200**, and transmitting the TIP level data and TIP position signal to the TIP level data T/R unit **111** of the process computer **100**.

For the data transmitting unit **300** that transmits the TIP level data and the TIP position signal, which are digital signals, a hub or the like is used, for example.

A normal operation of the present embodiment will be described below.

The process computer **100** is equipped with the operation input unit **101**. An operator uses the operation input unit **101** to make a request for a TIP scanning signal (scanning start/interrupt signal), or to specify a TIP guide tube **530** for which a neutron flux level is measured.

A signal requested and specified by the operator is processed by the TIP scanning unit **110** of the process computer **100** before being output to the TIP driving control unit **201** of the TIP control panel **200**.

On the TIP control panel **200**, an operation section **210** is provided. Through a switch on the operation section **210**, the operator can carry out an operation of making a driving request and a pull-out/insertion request to the detector. Based on a TIP scanning signal from the process computer **100** or an instruction from the operation section **210**, the TIP driving control unit **201** outputs a driving signal (insertion/pull-out signal for the detector) to the TIP driving equipment **570**.

The TIP driving equipment **570** drives the TIP detector **540** in a direction corresponding to the driving signal.

Meanwhile, the neutron flux level measured by the TIP detector **540** is input, as a TIP level signal, to the TIP level data accumulation unit **204** of the TIP control panel **200** via the TIP level processing unit **202** of the TIP control panel **200**.

The height from the core top to core bottom of the TIP detector **540** is input, as a TIP position signal that is generated as the TIP detector **540** is inserted from the core bottom to the core top and pulled out of the core top to the core bottom, to the TIP level data accumulation unit **204** via the TIP position processing unit **203** of the TIP control panel **200**.

The TIP level data accumulation unit **204** reads a TIP level signal in synchronization with a TIP position signal, and stores the TIP level signal as TIP level data.

The TIP level data stored in the TIP level data accumulation unit **204** is handed over from the TIP level data T/R unit **205** to the TIP level data T/R unit **111** of the process computer **100** via the data transmitting unit **300** at a time when the scanning of each string is completed.

The TIP position signal stored in the TIP level data accumulation unit **204** is constantly handed over from the TIP level data T/R unit **205** of the TIP control panel **200**, in order to be synchronized with an LPRM level signal and an APRM level signal, to the TIP level data T/R unit **111** of the process computer **100** via the data transmitting unit **300**.

The TIP level data input to the TIP level data T/R unit **111** of the process computer **100** becomes synchronized with the LPRM level signal and the APRM level signal before being stored in the TIP level data storage unit **112** of the process computer **100**.

Measurement data stored in the TIP level data storage unit **112** of the process computer **100** are displayed on the display unit **102** by the TIP scanning unit **110**, and a log thereof is printed on the print unit **103**. Moreover, the measurement data are transferred to a core performance processing unit **113**, where the measurement data are used as a basis for calculating a reactor power distribution.

Here, the TIP level data accumulation unit **204** of the TIP control panel **200** needs to perform a process of accumulating TIP level data at high speed in order to make it possible to increase the driving speed of the TIP detector **540** and detect the position with a high degree of accuracy at intervals of 0.1 inch. Therefore, it is necessary to form the TIP level data accumulation unit **204** independently of the TIP driving control unit **201** of the TIP control panel **200**. The description thereof will be provided below.

FIG. **2** is a flowchart showing the flow of a process by the TIP level data accumulation unit according to the present embodiment.

FIG. **3** is an explanatory diagram showing the configuration of TIP level data according to the present embodiment.

In the TIP level data accumulation unit **204**, after the measurement of a TIP level starts, the current time, a TIP position and a TIP level are simultaneously input during a period of time when the TIP detector **540** is inserted from the core bottom to the core top and during a period of time when the TIP detector **540** is pulled out of the core top to the core bottom. The above three sets of data are packaged into one group, which is then stored in TIP level data.

That is, as shown in FIG. **2**, measurement starts to take place from the core bottom, and the current time is input (Step S**01**). A TIP position signal is input into the TIP position processing unit **203** (Step S**02**). A TIP level signal is input into the TIP level processing unit **202** (Step S**03**). The above current time, TIP position and TIP level are combined in one group before being stored in the TIP level data accumulation unit **204** (Step S**04**).

As shown in FIG. **2**, while a confirmation is being made as to whether the TIP detector is in an insertion state, which is from the core bottom to the core top, or in a pull-out state, which is from the core top to the core bottom (Step S**05**), the process is repeated every 0.1 inch as a TIP position. After it is determined that the TIP detector has returned to the core bottom, the process comes to an end.

The TIP level data stored in the TIP level data accumulation unit **204** are stored, as shown in FIG. **3**, as to No. **01** to No. **10** channels for each of first to fifth TIP detectors.

The TIP level data T/R unit **111** of the process computer **100** needs to perform a process of receiving a TIP position signal from the data transmitting unit **300** at high speed in order to make it possible to read an LPRM level signal and an APRM signal in synchronization with the TIP position signal. And, it is necessary to form the TIP level data T/R unit **111** independently of the TIP scanning unit **110** of the process computer **100**.

FIG. **4** is a flowchart showing the flow of a process by the TIP level data T/R unit **111** of reading an LPRM level signal and an APRM level signal according to the present embodiment.

The current position of the TIP detector **540** is input by the data transmitting unit **300** (Step S**11**). A determination is made as to whether the position of the TIP detector **540** is the center of the core (Step S**12**). If the determination result is YES, an APRM level signal is stored in the TIP level data storage unit **112** (Step S**13**) before the process proceeds to the next step S**14**. If the determination result is NO at step S**12**, the process just proceeds to the next step S**14**.

Then, a determination is made as to whether or not the position of the TIP detector **540** is the core bottom or the core top (Step S**14**). If the determination result is YES, the LPRM level signal and the APRM level signal are stored in the TIP level data storage unit **112** (Step S**15**), and the process subsequently proceeds to the next step S**16**. If the determination result is NO at step S**14**, the process just proceeds to the next step S**16**.

While a confirmation is being made as to whether the TIP detector **540** is in an insertion state, which is from the core bottom to the core top, or in a pull-out state, which is from the core top to the core bottom (Step S**16**), the above operations are repeated at high speed for each TIP position. The process eventually comes to an end after it is determined that the TIP detector **540** has returned to the core bottom.

The TIP level data T/R unit **111** makes a determination, from the current TIP position signal, as to whether the TIP detector **540** is positioned at the core bottom, core center, or core top; the LPRM level signals and APRM level signals of corresponding heights are stored in the TIP level data storage unit **112**. The above determination process is repeated at high speed. The LPRM levels and APRM levels stored in the TIP level data storage unit **112** are stored for all channels of each TIP detector **540**.

As described above, according to the present embodiment, the TIP level signals and the TIP position signals are synchronously collected by the TIP level data accumulation unit **204** of the TIP control panel **200**. Moreover, the TIP position signals are constantly transmitted from the TIP control panel **200** to the process computer **100**. Therefore, the LPRM level signals and the APRM signals are collected also by the process computer **100** in synchronization with the TIP position signals.

As a result, without being constrained by the driving time of the TIP detector **540** due to the hardware of the process computer **100**, and without being affected by a transfer lag of a signal, a delay of a timing at which the process computer **100** detects that the pulse signal is ON, or the like, the TIP driving speed can be raised. Moreover, it is possible to measure the TIP level signals in synchronization with the TIP position signals without error.

Moreover, the LPRM level signals and the APRM level signals, which are required as basic data for calculation of a reactor power distribution, can be input in synchronization with the TIP position signals with the same degree of accuracy as a conventional one.

As for the degree of effectiveness, since a multitask having a large number of functions, i.e. a variety of programs, is executed by the process computer, there is a limit on a high-speed reading performance of a TIP position pulse of a task. It is possible to move the TIP detector only at a speed of three inches per second (76.2 mm).

Meanwhile, according to the present embodiment, in the TIP control panel **200**, which is a dedicated equipment, the TIP level signals and the TIP position signals are synchronized and turned into data before being output to the process computer **100**. Therefore, without being affected by the high-speed reading performance limitations of a TIP position pulse of the process computer, it is possible to increase the speed of the TIP detector with the performance of the TIP control equipment's side.

For example, suppose that, with the driving performance of the TIP driving equipment **570**, it is basically possible to move the TIP detector at a speed of 12 inches (304.8 mm) per second. In this case, without being affected by conventional constraints, the driving can be carried out at the above speed. A simple estimation reveals that the speed can be quadrupled. In that case, it takes about 15 to 30 minutes to complete, whereas a conventional method requires one to two hours in measuring all strings.

Furthermore, for each string, a TIP reading value data package can be created in synchronization with the position of the TIP detector **540**. As a transmission interface, a transmission mechanism that uses hubs and Ethernet is provided, for example. As a result, instead of about 13 kilometers of metal I/O cables that are required for inputting and outputting of a TIP level signal, a TIP position signal and the like between the process computer **100** and the TIP control panel **200**, what is required is only one network cable, which is for example a twisted pair cable. As a result, it is possible to significantly reduce the amount of cables.

[Second Embodiment]

FIG. **5** is a block diagram showing the configuration of a second embodiment of a TIP system of the present invention.

The TIP system of the present embodiment is a variant of the first embodiment. The process computer **100** includes a plant state monitoring unit **121**. To the plant state monitoring unit **121**, a plant state signal and an output from the TIP level data storage unit **112** are input. The plant state monitoring unit **121** outputs a result of a calculation process of stability diagnosis to the TIP scanning unit **110**.

The other components are substantially the same as those in the first embodiment.

The following describes an operation of the present embodiment.

A scanning start request or scanning termination request input by an operator via the operation input unit **101** of the process computer **100** is processed by the TIP scanning unit **110** of the process computer **100**, and is output to the TIP driving control unit **201** of the TIP control panel **200**, as well as to the plant state monitoring unit **121** in parallel.

The plant state monitoring unit **121** takes in a plant state signal, which includes a reactor thermal power, a core flow rate, a control-rod position and the like. When a scanning start request is input from the TIP scanning unit **110**, the plant state monitoring unit **121** starts monitoring. When trouble is detected in the state of the plant, a scanning interrupt request is output to the TIP scanning unit **110**, and the detection information thereof is issued to the operator through the operation input unit **101**.

After receiving a scanning termination signal from the TIP scanning unit **110**, the plant state monitoring unit **121** stops monitoring.

In this case, as for the monitoring of the state of the plant in which a TIP level is being measured by the plant state monitoring unit **121**, depending on the type of a to-be-monitored plant state signal, there are several patterns. Therefore, a process needs to be prepared for each type.

FIG. **6** is a flowchart showing the flow of a process of monitoring the state of the plant in which a TIP level is being measured according to the present embodiment, i.e. the flow of a process of monitoring the plant's state at a timing when a TIP level of each LPRM string is measured during a period of time from when the measurement starts until the measurement comes to an end. The plant state signal is of a reactor thermal power, core flow rate, or control-rod position.

The flow of the process will be sequentially described below.

In the plant state monitoring unit **121**, after a measurement start request is input from an operator, a plant state signal at the time is stored as starting data (Step S**21**).

Then, a plant state signal that comes after the measurement of a TIP level of one LPRM string is completed is stored as per-string data (Step S**22**). A determination is made as to whether the difference between the starting data and the per-string data is less than a certain threshold value (Step S**23**). The operations of steps S**21** and S**22** are repeated for all LPRM strings.

A determination is made as to whether the difference between the starting data and the per-string data exceeds a certain threshold value (Step S**23**). If the difference exceeds the threshold value, it is determined that trouble has occurred. The operator is notified of the fact via the TIP scanning unit **110**, and the TIP scanning is interrupted (Step S**24**).

The above assessment process is performed every time TIP levels of all the LPRM strings are measured as shown in FIG. **6**. A change of the plant state signal that is being measured is monitored.

When a scanning termination request is input from the operator, a plant state signal at the time is stored as terminating data (Step S**25**).

Then, a determination is made as to whether the difference between the starting data and the per-string data exceeds a certain threshold value (Step S**26**). If the difference exceeds the threshold value, the plant is decided as having trouble. The operator is notified of the fact via the TIP scanning unit **110** (Step S**27**).

Alternatively, in a process of monitoring the control-rod position, the following method may also be applicable: Based on the changed coordinates of a control rod **670** and the amount of change, an influence rate is calculated from an influence-rate evaluation table that is prepared in advance, and it is determined, depending on the influence rate, that trouble has occurred.

The present assessment process makes it possible to capture the power variation of the entire plant.

FIG. **7** is a flowchart showing the flow of a process by the plant state monitoring unit **121** that is measuring a TIP level according to the present embodiment, and shows a monitoring operation of a TIP level.

In the plant state monitoring unit **121**, the TIP level data that appear at a time when the TIP detector is inserted from the core bottom to the core top and are in the TIP level data storage unit **112** are taken out (Step S**31**). Furthermore, the TIP level data that appear at a time when the TIP detector is pulled out of the core top to the core bottom are also taken out (Step S**32**).

The TIP level data at the same height during insertion and during pullout are taken out (Step S**33**).

A determination is made as to whether the difference between TIP levels at the same heights of the during insertion data and during pullout data is less than a threshold value (Step S**34**). If the difference is less than the threshold value at all heights, the operations of steps S**31** to S**33** are repeated.

The above assessment process is performed every time TIP levels of all LPRM strings are measured as shown in FIG. **7**; and it is monitored whether the TIP levels are abnormal.

If the difference between TIP levels at the same height of the during-insertion data and the during-pullout data exceeds a certain threshold value at least at one height, it is determined that trouble has occurred in the measurement of the TIP level of the corresponding string. The operator is notified of the fact via the TIP scanning unit **110**, and the TIP scanning is interrupted (Step S**35**).

The present assessment process makes it possible to accurately detect abnormal TIP levels.

FIG. **8** is a flowchart showing the flow of a process of monitoring the state of the plant in which a TIP level is being measured according to the present embodiment, which is a process of monitoring the driving time of the TIP detector **540**.

In the plant state monitoring unit **121**, the time stamp of the TIP level data, which appear at a time when the TIP detector has reached the core bottom and are in the TIP level data storage unit **112**, are taken out (Step S**41**). Then, the time stamp of the TIP level data that appear at a time when the TIP detector has reached the core top are taken out (Step S**42**).

While a determination is made as to whether the difference between the core-bottom arrival time and the core-top arrival time is less than a specified time length (Step S**43**), the operations of steps S**41** and S**42** are repeated for all LPRM strings.

If it is determined that the difference exceeds the specified time length, then it is determined that trouble has occurred in the measurement of a TIP level of the corresponding string. The operator is notified of the fact via the TIP scanning unit **110**, and the TIP scanning is interrupted (Step S**44**).

As another monitoring parameter, the time needed for the TIP detector to be pulled out of the core top to the core bottom may also be available.

The present assessment process makes it possible to capture the abnormal driving state of the TIP detector.

According to the present embodiment, the plant state monitoring unit **121** in the process computer **100** monitors several types of plant state signals when a TIP level is being measured. When the reactor thermal power, core flow rate or control-rod position has changed, the operator is notified of the fact, or abnormal data are discarded. Therefore, it is possible to collect TIP level data in a way that properly reflects the current power distribution, as well as to prevent deterioration in the accuracy of reactor power distribution calculation.

Moreover, according to the present embodiment, as in the first embodiment, it is possible to provide a high-speed TIP monitoring control equipment that is not affected by the driving time of the TIP detector, a transfer lag of a signal, a delay of a timing at which the process computer detects that the pulse signal is ON, or the like.

[Third Embodiment]

FIG. **9** is a block diagram showing the configuration of a third embodiment of a TIP system of the present invention.

The TIP system of the present embodiment is a variant of the first embodiment. The process computer **100** includes a calibration current value calculation unit **131**, a first calibration current value data storage unit **132***a*, and a calibration current value data transmitting and receiving (T/R) unit **133**. The TIP control panel **200** of the present embodiment includes a calibration current value data transmitting and receiving (T/R) unit **231** and a calibration current value setting unit **232**.

The other components are substantially the same as those in the first embodiment.

In the process computer **100**, the calibration current value calculation unit **131** calculates, on the basis of the value of a TIP level of a common string stored in the TIP level data storage unit **112**, a calibration current value of the TIP detector **540**. The first calibration current value data storage unit **132***a* stores, in the process computer **100**, data of the calibration current value calculated by the calibration current value calculation unit **131**.

The calibration current value data T/R unit **133** transmits the calibration current value data from the process computer **100** to the TIP control panel **200** via the data transmitting unit **300**.

The calibration current value data T/R unit **231** receives the calibration current value data calculated by the process computer **100**. The calibration current value setting unit **232** adjusts the gain of the TIP detector **540** in accordance with the calibration current value data T/R unit **231** of the TIP control panel **200** and the calibration current value.

A normal operation of the TIP monitoring control equipment **10** of the present embodiment will be described below.

In the calibration current value calculation unit **131** of the process computer **100**, on the basis of the TIP level of a common string of the TIP level data storage unit **112** of the process computer **100**, the calibration current value of the TIP detector **540** is calculated.

In this case, a common string is a common TIP guide tube **530** that enables all TIP detectors **540** to measure TIP levels, and is equivalent to No. **10** channel (LPRM string coordinates **32-33**) in the conceptual diagram of the in-core arrangement of PPM strings of FIG. **16**.

The calibration current value is a current value that is so set that the average of TIP level signals of common strings measured by the TIP detector **540** is 100 at a time when the reactor power is 100%, and is a value used to adjust the gain of the TIP detector **540** so that a TIP level signal is generated in accordance with the current reactor power.

The calibration current value needs to be set for each TIP detector **540**. As the detector becomes deteriorated, a larger calibration current value is required to compensate for the deterioration.

Data of the calibration current value calculated by the calibration current value calculation unit **131** of the process computer **100** is stored in the first calibration current value data storage unit **132***a* of the process computer **100**. The calibration current value data T/R unit **133** of the process computer **100** outputs the calibration current value data from the process computer **100** to the TIP control panel **200** via the data transmitting unit **300**.

The calibration current value data T/R unit **231** of the TIP control panel **200** receives the calibration current value data transmitted from the process computer **100**. The calibration current value data are output to the calibration current value setting unit **232** of the TIP control panel.

In the calibration current value setting unit **232**, a TIP-level process that uses the calibration current value set in the TIP level processing unit **202** is performed, and the gain of the TIP detector is adjusted.

Moreover, according to the present embodiment, as in the first embodiment, it is possible to provide a high-speed TIP monitoring control equipment that is not affected by the driving time of the TIP detector, a transfer lag of a signal, a delay of a timing at which the process computer detects that the pulse signal is ON, or the like.

[Fourth Embodiment]

FIG. **10** is a block diagram showing the configuration of a fourth embodiment of a TIP system of the present invention.

The TIP system of the present embodiment is a variant of the third embodiment.

The present embodiment will be described based on FIG. **10**.

As shown in FIG. **10**, according to the present embodiment, in the process computer **100**, a TIP detector deterioration diagnosis unit **140** is provided. The other components are substantially the same as those in the third embodiment.

When the measurement of a TIP level is performed, a calibration current value of the TIP detector **540** is calculated by the calibration current value calculation unit **131** of the process computer **100**. In a second calibration current value data storage unit **132***b* of the process computer **100**, the date and time when calibration takes place is added to data of the calculated calibration current value, and the data are stored and saved.

In the TIP detector deterioration diagnosis unit **140** of the process computer **100**, a long-term deterioration trend of the calibration current value of each TIP detector **540** is determined from the second calibration current value data storage unit **132***b*. In the format that the operator desires, the trend is displayed on the display unit **102**, and a log thereof is printed on the print unit **103**, thereby notifying the operator.

Incidentally, as the format that the operator desires, for example, the following and other functions are conceivable: a function of plotting TIP gain data together with replacement recommendation gain and automatically notifying the operator of the fact that a replacement time has come; and a function of notifying, at a time when the deviation of gain between TIP machines becomes larger, the operator of trouble of the corresponding TIP detector **540**.

FIG. **11** is an explanatory diagram showing the configuration of the second calibration current value data storage unit **132***b* of the present embodiment.

FIG. **12** is an explanatory diagram showing an example of a deterioration assessment screen of the TIP detector **540** by the TIP detector deterioration diagnosis unit **140** according to the present embodiment.

As for the configuration of the second calibration current value data storage unit **132***b* of the process computer **100**, as shown in FIG. **10**, the date and time when the calibration current value data are calculated and the calibration current value are saved as a pair of data for several years for all TIP detectors **540**.

On the TIP detector deterioration diagnosis screen, a trend is displayed making it easier to visually confirm a long-term deterioration trend of the TIP detector **540**; and, as information useful for making a plan of the replacement time of the TIP detector **540**, a warning that is issued when the threshold value is exceeded, a replacement recommendation time that is calculated from a deterioration rate of the calibration current value, and the like are displayed.

According to the present embodiment, in addition to the same advantageous effects as those in the third embodiment, in the process computer **100**, it is possible to determine a long-term deterioration trend of the TIP detector **540** by having a function of keeping the second calibration current value data storage unit **132***b* for a long period of time after the date and time data are added to the calibration current value data, and of displaying the TIP gain on the screen in the format that the operator desires, or printing on a printer, in the TIP detector deterioration diagnosis unit **140**.

Thus, it is also possible to make a plan accurately of the replacement time of the TIP detector **540**.

[Other Embodiments]

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of inventions. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

The invention claimed is:

1. A TIP monitoring control system for controlling a TIP driving equipment that drives a TIP detector in a LPRM string, the TIP monitoring control system comprising: a process computer, a TIP control panel, and a data transmission unit configured to transmit data between the TIP control panel and the process computer, wherein

the TIP control panel includes:

a TIP driving control unit that is programmed to input a TIP scanning signal and to output a driving signal to the TIP driving equipment, a TIP level processing unit that is programmed to input a TIP level signal from the TIP detector,

a TIP position processing unit that is programmed to input a TIP position signal from the TIP driving equipment,

a TIP level data accumulation unit that is programmed to input the TIP level signal and the TIP position signal and to accumulate the TIP level signal in synchronization with a TIP position signal as TIP level data, and

a TIP level data transmitting unit that is programmed to constantly transmit the TIP position signal through the data transmission unit and to collectively transmit the TIP level data through the data transmission unit;

the process computer includes:

a TIP scanning unit that is programmed to output the TIP scanning signal,

a TIP level data receiving unit that is programmed to receive 1) the TIP level data accumulated in the TIP control panel through the data transmission unit, 2) an LPRM level signal from an LPRM detector, and 3) an APRM level signal from an APRM, and receive the TIP position signal constantly,

a TIP level data storage unit that is programmed to store the LPRM level signal and the APRM level signal in synchronization with the constantly received TIP position signal, and the TIP level data synchronized with the TIP position signal in the accumulation unit;

a calibration current value calculation unit that is programmed to calculate a calibration current value of a TIP detector on the basis of each TIP level data of a common string stored in the TIP level data storage unit,

a first calibration current value data storage unit that is programmed to store calibration current value data calculated by the calibration current value calculation unit, and

a first calibration current value data transmitting and receiving unit that is programmed to transmit calibration current value data from the process computer to the TIP control panel via the data transmission unit; and

the TIP control panel further includes:

a second calibration current value data transmitting and receiving unit that is programmed to receive calibration current value data calculated by the process computer via the data transmission unit, and

a calibration current value setting unit that is programmed to adjust gain of the TIP detector in accordance with a calibration current value.

2. The TIP monitoring control system according to claim **1**, wherein

the process computer further includes a plant state monitoring unit that is programmed to monitor parameters based upon a plant state signal, a TIP position signal stored in the TIP level data storage unit, and a TIP level signal that is in synchronization with the TIP position signal.

3. The TIP monitoring control system according to claim **1**, wherein

the process computer further includes:

a second calibration current value data storage unit in which information representing a time when calibration takes place is added to calibration current value data calculated by the calibration current value calculation unit before the calibration current value data are stored; and

a TIP detector deterioration diagnosis unit that is programmed to determine a deterioration trend of the TIP detector from the calibration current value data storage unit and outputs the trend.

4. A TIP system comprising: a plurality of TIP detectors, a selection mechanism that sequentially selects one of a plurality of TIP guide tubes for each of the TIP detectors, a shielded container in which the TIP detectors are stored in any time other than a measurement period of the TIP detectors, a TIP driving equipment that drives the insertion and pullout of the TIP detectors into the TIP guide tubes, and a TIP monitoring control system, wherein the TIP monitoring control system has: a process computer, a TIP control panel, and a data transmission unit,

the TIP control panel including:

a TIP driving control unit that is programmed to input a TIP scanning signal and to output a driving signal to the TIP driving equipment,

a TIP level processing unit that is programmed to input a TIP level signal from the TIP detector,

a TIP position processing unit that is programmed to input a TIP position signal from the TIP driving equipment,

a TIP level data accumulation unit that is programmed to input the TIP level signal and the TIP position signal and to accumulate the TIP level signal in synchronization with a TIP position signal as TIP level data, and

a TIP level data transmitting unit that is programmed to constantly transmit the TIP position signal through the data transmission unit and to collectively transmit the TIP level data through the data transmission unit;

the process computer including:

a TIP scanning unit that is programmed to output the TIP scanning signal,

a TIP level data receiving unit that is programmed to receive 1) the TIP level data accumulated in the TIP control panel through the data transmission unit, 2) an LPRM level signal from an LPRM detector, and 3) an APRM level signal from an APRM, and receive the TIP position signal constantly,

a TIP level data storage unit that is programmed to store the LPRM level signal and the APRM level signal in synchronization with the constantly received TIP position signal, and the TIP level data synchronized with the TIP position signal in the accumulation unit;

a calibration current value calculation unit that is programmed to calculate a calibration current value of a TIP detector on the basis of each TIP level data of a common string stored in the TIP level data storage unit,

a first calibration current value data storage unit that is programmed to store calibration current value data calculated by the calibration current value calculation unit, and

a first calibration current value data transmitting and receiving unit that is programmed to transmit calibration current value data from the process computer to the TIP control panel via the data transmission unit; and

the TIP control panel further includes:

a second calibration current value data transmitting and receiving unit that is programmed to receive calibration current value data calculated by the process computer via the data transmission unit, and a calibration current value setting unit that is programmed to adiust gain of the TIP detector in accordance with a calibration current value.

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